(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 028 586 A2

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
16.08.2000 Bulletin 2000/33

(51) Int Cl.[7]: **H04N 1/60**

(21) Application number: **99309859.9**

(22) Date of filing: **08.12.1999**

(84) Designated Contracting States:
AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE
Designated Extension States:
AL LT LV MK RO SI

(30) Priority: **27.01.1999 JP 1821799**
16.11.1999 JP 32600599

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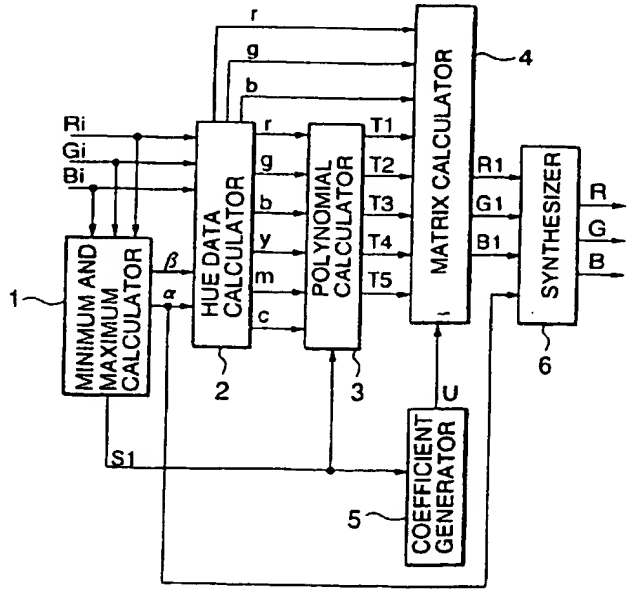
(54) Color conversion device and color conversion method

(57) By changing coefficients of first comparison-result data relating to respective hues, and and second comparison-result data relating to respective inter-hue areas, only the target hue or inter-hue area among the six hues of red, blue, green, yellow, cyan, and magenta, and the six inter-hue areas can be varied, without affecting other hues and inter-hue areas. Thus, the six hues and six inter-hue areas can be varied independently, and the large-capacity memory is not required.

FIG.1



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Description

BACKGROUND OF THE INVENTION

[0001] The present invention relates to data processing used for a full-color printing related equipment such as a printer, a video printer, a scanner or the like, an image processor for forming computer graphic images or a display device such as a monitor. More specifically, the invention relates to a color conversion device and a color conversion method for performing color conversion from image data in the form of a first set of three color data of red, green and blue, or cyan, magenta and yellow, to a second set of three color data of red, green and blue, or cyan, magenta and yellow.

[0002] Color conversion in printing is an indispensable technology for compensating deterioration of image quality due to color mixing property due to the fact that the ink is not of a pure color, or the non-linearity (in the hue) of the image-printing, and to output a printed image with a high color reproducibility. Also, in a display device such as a monitor or the like, color conversion is performed in order to output (display) an image having desired color reproducibility in accordance with conditions under which the device is used or the like when an inputted color signal is to be displayed.

[0003] Conventionally, two methods have been available for the foregoing color conversion: a table conversion method and a matrix calculation method.

[0004] The table conversion method is a method for inputting image data of red, green and blue (which may hereinafter be referred simply as "R, G and B") and obtaining image data of R, G and B stored beforehand in a memory such as ROM or complementary color data of yellow, magenta and cyan (which may hereinafter be referred simply as "Y, M and C"). Since an arbitrary conversion characteristic can be employed, this table conversion method has an advantageous capability of executing color conversion with good color reproducibility.

[0005] However, in a simple structure for storing data for each combination of image data, a large-capacity memory of about 400 Mbit must be used. For example, even in the case of a compression method for memory capacity disclosed in Japanese Patent Kokai Publication No. S63-227181, memory capacity is about 5 Mbit. Therefore, a problem inherent in the table conversion system is that since a large-capacity memory is necessary for each conversion characteristic, it is difficult to implement the method by means of an LSI, and it is also impossible to deal with changes in the condition under which the conversion is carried out.

[0006] On the other hand, in the case of the matrix calculation method, for example, for obtaining printing data of Y, M and C from image data of R, G and B, the following formula (11) is used as a basic calculation formula.

$$\begin{bmatrix} Y \\ M \\ C \end{bmatrix} = (Aij) \begin{bmatrix} R \\ G \\ B \end{bmatrix} \qquad \ldots(11)$$

[0007] Here, Aij represents coefficients, with $i = 1$ to 3, and $j = 1$ to 3.

[0008] However, by the simple linear calculation of the formula (11), it is impossible to provide a good conversion characteristic because of a non-linearity of an image-printing or the like.

[0009] A method has been proposed for providing a conversion characteristic to improve the foregoing characteristic. This method is disclosed in Japanese Patent Application Kokoku Publication H2-30226, directed to "color correction calculation device, and employs a matrix calculation formula (12) below.

$$\begin{bmatrix} Y \\ M \\ C \end{bmatrix} = (Dij) \begin{bmatrix} R \\ G \\ B \\ R*G \\ G*B \\ B*R \\ R*R \\ G*G \\ B*B \\ N \end{bmatrix} \qquad \ldots(12)$$

[0010] Here, N is a constant, i = 1 to 3, and j = 1 to 10.

[0011] In the foregoing formula (12), since image data having a mixture of an achromatic component and a color component is directly used, mutual interference occur in computation. In other words, if one of the coefficients is changed, influence is given to the components or hues other than the target component or hue (the component or hue for which the coefficient is changed). Consequently, a good conversion characteristic cannot be realized.

[0012] A color conversion method disclosed in Japanese Patent Application Kokai Publication H7-170404 is a proposed solution to this problem. Fig. 19 is a block circuit diagram showing the color conversion method for conversion of image data of R, G and B into printing data of C, M and Y, disclosed in Japanese Patent Application Kokai Publication H7-170404. In the drawing, reference numeral 100 denotes a complement calculator; 101, an minimum and maximum calculator; 102, a hue data calculator; 103, a polynomial calculator; 104, a matrix calculator; 105, a coefficient generator; and 106, a synthesizer.

[0013] Next, the operation will be described. The complement calculator 100 receives image data R, G and B, and outputs complementary color data Ci, Mi and Yi which have been obtained by determining 1's complements.

[0014] The determination of 1's complement of an input data can be achieved by subtracting the value of the input data of n bits (n being an integer) from (2^n-1). For example, in the case of 8-bit data, the value of the input data is deducted from "255".

[0015] The minimum and maximum calculator 101 outputs a maximum value β and a minimum value α of this complementary color data and an identification code S for indicating, among the six hue data, data which are zero.

[0016] The hue data calculator 102 receives the complementary color data Ci, Mi and Yi and the maximum and minimum values β and α, and outputs six hue data r, g, b, y, m and c which are obtained by executing the following subtraction:

$$r = \beta - Ci,$$

$$g = \beta - Mi,$$

$$b = \beta - Yi,$$

$$y = Yi - \alpha,$$

$$m = Mi - \alpha,$$

and

$$c = Ci - \alpha.$$

Here, among the six hue data, at least two assume the value zero.

[0017] The polynomial calculator 103 receives the hue data and the identification code S, selects, from r, g and b, two data Q1 and Q2 which are not zero and, from y, m and c, two data P1 and P2 which are not zero. Based on these data, the polynomial calculator 103 computes polynomial data:

$$T1 = P1 * P2,$$

$$T3 = Q1 * Q2,$$

$$T2 = T1/(P1 + P2),$$

and

$$T4 = T3/(Q1 + Q2),$$

and then outputs the results of the calculation.

[0018] The coefficient generator 105 generates calculation coefficients U(Fij) and fixed coefficients U(Fij) for the polynomial data based on information regarding the identification code S. The matrix calculator 104 receives the hue data y, m and c, the polynomial data T1 to T4 and the coefficients U, and outputs a result of the following formula (13) as color ink data C1, M1 and Y1.

$$\begin{bmatrix} C1 \\ M1 \\ Y1 \end{bmatrix} = (Eij)\begin{bmatrix} c \\ m \\ y \end{bmatrix} + (Fij)\begin{bmatrix} c*m \\ m*y \\ y*c \\ r*g \\ g*b \\ b*r \\ c*m/(c+m) \\ m*y/(m+y) \\ y*c/(y+c) \\ r*g/(r+g) \\ g*b/(g+b) \\ b*r/(b+r) \end{bmatrix} \quad \ldots(13)$$

[0019] The synthesizer 106 adds together the color ink data C1, M1 and Y1 and data α which is the achromatic data, and outputs printing data C, M and Y. Accordingly, the following formula (14) is used for obtaining printing data.

$$\begin{bmatrix} C \\ M \\ Y \end{bmatrix} = (Eij)\begin{bmatrix} c \\ m \\ y \end{bmatrix} + (Fij)\begin{bmatrix} c*m \\ m*y \\ y*c \\ r*g \\ g*b \\ b*r \\ c*m/(c+m) \\ m*y/(m+y) \\ y*c/(y+c) \\ r*g/(r+g) \\ g*b/(g+b) \\ b*r/(b+r) \end{bmatrix} + \begin{bmatrix} \alpha \\ \alpha \\ \alpha \end{bmatrix} \quad \ldots(14)$$

[0020] The formula (14) shows a general formula for a group of pixels.

[0021] Fig. 20A to Fig. 20F, which are schematic diagrams, show relations between six hues of red (R), green (G), blue (B), yellow (Y), cyan (C) and magenta (M), and hue data y, m, c, r, g and b. As shown, each hue data relates to three hues (i.e., extends over the range of three hues). For instance the hue data c relates to the hues g, c and b.

[0022] Fig. 21A to Fig. 21F, which are schematic diagrams, show relations between the six hues and product terms y*m, r*g, c*y, g*b, m*c and b*r.

[0023] As shown, each of the six product terms y*m, m*c, c* y, r*g, g*b and b*r in the formula (14) relates to only one hue among the six hues of red, blue, green, yellow, cyan and magenta. That is, only y*m is an effective product term for red; m*c for blue; c*y for green; r*g for yellow; g*b for cyan; and b*r for magenta.

[0024] Also, each of the six fraction terms y*m/(y + m), m* c/(m + c), c*y/(c + y), r*g/(r + g), g*b/(g + b) and b*r/(b + r) in the formula (14) relates to only one hue among the six hues.

[0025] As apparent from the foregoing, according to the color conversion method shown in Fig. 19, by changing coefficients for the product terms and the fraction terms regarding the specific hue, only the target hue can be adjusted without influencing other hues.

[0026] Each of the foregoing product terms is determined by a second-order computation for chroma, and each of the fraction terms is determined by a first-order computation for chroma. Thus, by using both of the product terms and

the fraction terms, the non-linearity of an image-printing for chroma can be adjusted.

[0027] However, this color conversion method cannot satisfy a certain desire. That is, depending on the user's preference, if an area in a color space occupied by specific hues is to be expanded or reduced, e.g., specifically, if expansion or reduction in an area of red in a color space including magenta, red and yellow is desired, the conventional color conversion method of the matrix computation type could not meet such a desire.

[0028] The problems of the conventional color conversion method or color conversion device are summarized as follows. Where the color conversion device is of a table conversion method employing a memory such as ROM, a large-capacity memory is required, and a conversion characteristic cannot be flexibly changed. Where the color conversion device is of a type using a matrix calculation method, although it is possible to change only a target hue, it is not possible to vary the inter-hue areas between adjacent ones of the six hues of red, blue, green, yellow, cyan and magenta, and good conversion characteristics cannot be realized throughout the entire color space.

SUMMARY OF THE INVENTION

[0029] The present invention was made to solve the foregoing problems. An object of the present invention is to provide a color conversion device and a color conversion method for performing color-conversion wherein independent adjustment is performed not only for six hues of red, blue, green, yellow, cyan and magenta but also six inter-hue areas of red-yellow, yellow-green, green-cyan, cyan-blue, blue-magenta and magenta-red,
and a conversion characteristic can be flexibly changed, and no large-capacity memories are necessary.

[0030] According to a first aspect of the invention, there is provided a color conversion device for performing pixel-by-pixel color conversion from a first set of three color data representing red, green and blue, or cyan, magenta and yellow, into a second set of three color data representing red, green and blue, or cyan, magenta, and yellow, said device comprising:

first calculation means for calculating a minimum value α and a maximum value β of said first set of three color data for each pixel;
hue data calculating means for calculating hue data r, g, b, y, m and c based on said first set of three color data, and said minimum and maximum values α and β outputted from said calculating means;
means for generating first comparison-result data based on the hue data outputted from said hue data calculating means;
means for generating second comparison-result data based on said first comparison-result data;
second calculation means for performing calculation using the hue data outputted from said hue data calculating means to produce calculation result data;
coefficient generating means for generating specified matrix coefficients for the hue data, the calculation result data, the first comparison-result data and the second comparison-result data; and
third calculation means responsive to said hue data, said first comparison-result data, said second comparison-result data, said calculation result data, and the coefficients from said coefficient generating means for calculating said second set of three color data, said means performing calculation including matrix calculation performed at least on said hue data, said first comparison-result data, said second comparison-result data, said calculation result data, and the coefficients from said coefficient generating means.

[0031] It may be so configured that said third calculation means performs said matrix calculation on said hue data, said first comparison-result data, said second comparison-result data, said calculation result data, and the coefficients from said coefficient generating means, and further includes synthesizing means for adding said minimum value α from said first calculation means to the results of said matrix calculation.

[0032] It may be so configured that

said coefficient generating means generates predetermined matrix coefficients Eij (i = 1 to 3, J = 1 to 3), and Fij (i = 1 to 3, j = 1 to 18), and
said third calculation means performs the calculation using the hue data, said said first comparison-result data, said second comparison-result data, said calculation result data, said minimum value α from said calculating means, and said matrix coefficients to determine the second set of three color data in accordance with the following formula (1):

$$\begin{bmatrix} R \\ G \\ B \end{bmatrix} = (Eij) \begin{bmatrix} r \\ g \\ b \end{bmatrix} + (Fij) \begin{bmatrix} c*m \\ m*y \\ y*c \\ r*g \\ g*b \\ b*r \\ h1r \\ h1g \\ h1b \\ h1c \\ h1m \\ h1y \\ h2ry \\ h2rm \\ h2gy \\ h2gc \\ h2bm \\ h2bc \end{bmatrix} + \begin{bmatrix} \alpha \\ \alpha \\ \alpha \end{bmatrix} \quad \ldots(1)$$

[0033] It may be so configured that

said coefficient generating means generates predetermined matrix coefficients Eij (i = 1 to 3, j = 1 to 3), and Fij (i = 1 to 3, j = 1 to 18), and

said third calculation means performs the calculation using the hue data, said said first comparison-result data,' said second comparison-result data, said calculation result data, said minimum value α from said calculating means, and said matrix coefficients to determine the second set of three color data in accordance with the following formula (2):

$$\begin{bmatrix} C \\ M \\ Y \end{bmatrix} = (Eij) \begin{bmatrix} c \\ m \\ y \end{bmatrix} + (Fij) \begin{bmatrix} c*m \\ m*y \\ y*c \\ r*g \\ g*b \\ b*r \\ h1r \\ h1g \\ h1b \\ h1c \\ h1m \\ h1y \\ h2ry \\ h2rm \\ h2gy \\ h2gc \\ h2bm \\ h2bc \end{bmatrix} + \begin{bmatrix} \alpha \\ \alpha \\ \alpha \end{bmatrix} \quad \ldots(2)$$

[0034] It may be so configured that said third calculation means performs said matrix calculation on said hue data, said first comparison-result data, said second comparison-result data, said calculation result data, the coefficients from said coefficient generating means, and said minimum value α from said first calculation means.

[0035] It may be so configured that

said coefficient generating means generates predetermined matrix coefficients Eij (i = 1 to 3, j = 1 to 3), and Fij (i = 1 to 3, j = 1 to 19), and

said third calculation means performs the calculation using the hue data, said said first comparison-result data, said second comparison-result data, said calculation result data, said minimum value α from said calculating means, and said matrix coefficients to determine the second set of three color data in accordance with the following formula (3):

$$\begin{bmatrix} R \\ G \\ B \end{bmatrix} = (Eij) \begin{bmatrix} r \\ g \\ b \end{bmatrix} + (Fij) \begin{bmatrix} c*m \\ m*y \\ y*c \\ r*g \\ g*b \\ b*r \\ h1r \\ h1g \\ h1b \\ h1c \\ h1m \\ h1y \\ h2ry \\ h2rm \\ h2gy \\ h2gc \\ h2bm \\ h2bc \\ \alpha \end{bmatrix} \quad \ldots(3)$$

[0036] It may be so configured that

said coefficient generating means generates predetermined matrix coefficients Eij (i = 1 to 3, j = 1 to 3), and Fij (i = 1 to 3, j = to 19), and
said third calculation means performs the calculation using the hue data, said said first comparison-result data, said second comparison-result data, said calculation result data, said minimum value α from said calculating means, and said matrix coefficients to determine the second set of three color data in accordance with the following formula (4):

$$\begin{bmatrix} C \\ M \\ Y \end{bmatrix} = (Eij) \begin{bmatrix} c \\ m \\ y \end{bmatrix} + (Fij) \begin{bmatrix} c*m \\ m*y \\ y*c \\ r*g \\ g*b \\ b*r \\ h1r \\ h1g \\ h1b \\ h1c \\ h1m \\ h1y \\ h2ry \\ h2rm \\ h2gy \\ h2gc \\ h2bm \\ h2bc \\ \alpha \end{bmatrix} \quad \ldots(4)$$

[0037] With the above arrangement, it is possible to independently vary, in addition to the six hues of red, blue, green, yellow, cyan and magenta, the six inter-hue areas of red-yellow, yellow-green, green-cyan, cyan-blue, blue-magenta, and magenta-red.
It is also possible to flexibly change the conversion characteristics, and the large-capacity memory is not required.

[0038] It may be so configured that

said first set of three color data represent red, green and blue,
said second set of three color data represent red, green and blue, and
said hue data calculation means calculates the hue data r, g, b, y, m, c by subtraction in accordance with:

$$r = Ri - \alpha,$$

$$g = Gi - \alpha,$$

$$b = Bi - \alpha,$$

$$y = \beta - Bi,$$

$$m = \beta - Gi,$$

and

$$c = \beta - Ri,$$

wherein Ri, Gi and Bi represent said first set of three color data.

[0039] It may be so configured that

said first set of three color data represent cyan, magenta and yellow,
said second set of three color data represent red, green and blue,
said device further comprises means for determining complement of said first set of three color data, and
said hue data calculation means calculates the hue data r, g, b, y, m, c by subtraction in accordance with:

$$r = Ri - \alpha,$$

$$g = Gi - \alpha,$$

$$b = Bi - \alpha,$$

$$y = \beta - Bi,$$

$$m = \beta - Gi,$$

and

$$c = \beta - Ri,$$

wherein Ri, Gi and Bi represent data produced by the determination of the complement said first set of three color data.

[0040] It may be so configured that

said first set of three color data represent cyan, magenta and yellow,
said second set of three color data represent cyan, magenta and yellow, and
said hue data calculation means calculates the hue data r, g, b, y, m, c by subtraction in accordance with:

$$r = \beta - Ci,$$

$$g = \beta - Mi,$$

$$b = \beta - Yi,$$

$$y = Yi - \alpha,$$

$$m = Mi - \alpha,$$

and

$$c = Ci - \alpha.$$

wherein Ci, Mi and Yi represent said first set of three color data.

[0041] It may be so configured that

said first set of three color data represent red, green and blue,
said second set of three color data represent cyan, magenta and yellow,
said device further comprises means for determining complement of said first set of three color data, and
said hue data calculation means calculates the hue data r, g, b, y, m, c by subtraction in accordance with:

$$r = \beta - Ci,$$

$$g = \beta - Mi,$$

$$b = = \beta - Yi,$$

$$y = Yi - \alpha,$$

$$m = Mi - \alpha,$$

and

$$c = Ci - \alpha.$$

wherein Ci, Mi and Yi represent data produced by the determination of the complement said first set of three color data.

[0042] With the above arrangement, the hue data calculating means can be configured of means for performing subtraction based on the input image R, G and B, or C, M and Y and the maximum value β and minimum value α from

the first calculation means.

[0043] It may be so configured that

said first comparison-result data generating means determines the comparison-result data among the hue data r, g and b, and the comparison-result data among the hue data y, m and c, and
said second comparison-result data generating means comprises multiplying means for multiplying the first comparison-result data outputted from said first comparison-result data generating means with specific calculation coefficients, and means for determining the comparison-result data based on the outputs of said multiplication means.

[0044] With the above arrangement, the first comparison-result data generating means and the second comparison-result data generating means are configured of means for performing comparison, and means for performing multiplication.

[0045] It may be so configured that

said first comparison-result data generating means determines the first comparison-result data:

$$h1r = \min(m, y),$$

$$h1g = \min(y, c),$$

$$h1b = \min(c, m),$$

$$h1c = \min(g, b),$$

$$h1m = \min(b, r),$$

and

$$h1y = \min(r, g),$$

(with min (A, B) representing the minimum value of A and B),
said second comparison-result data generating means determines the second comparison-result data:

$$h2ry = \min(aq1*h1y, ap1*h1r),$$

$$h2rm = \min(aq2*h1m, ap2*h1r),$$

$$h2gy = \min(aq3*h1y, ap3*h1g),$$

$$h2gc = \min(aq4*h1c, ap4*h1g),$$

$$h2bm = \min(aq5*h1m, ap5*h1b),$$

and

$$h2bc = \min (aq6*h1c, ap6*h1m).$$

[0046] With the above arrangement, the first comparison-result data generating means can be configured of means for performing minimum value selection, and the second comparison-result data can be configured of means for performing multiplication and means for performing minimum value selection.

[0047] It may be so configured that said multiplying means in said second comparison-result data generating means performs calculation on said first comparison result-data and said calculation coefficients by setting said calculation coefficients aq1 to aq6 and ap1 to ap6 to integral values of 2^n, with n being an integer, and by bit shifting.

[0048] With the above arrangement, the multiplication can be carried out by means of bit shifting.

[0049] It may be so configured that said second calculation means determines products of the hue data.

[0050] With the above arrangement, said second calculation means can be configured of means for performing multiplication.

[0051] It may be so configured that each of said first comparison-result data is determined from two of the hue data and is effective for only one of the six hues of red, green, blue, cyan, magenta and yellow.

[0052] With the above arrangement, each of the six hues can be adjusted by varying the coefficients for the first comparison-result data without influencing other hues.

[0053] It may be so configured that

each of said second comparison-result data is determined from two of the first comparison-result data and is effective for only one of the six inter-hue areas of red-yellow, yellow-green, green-cyan, cyan-blue, blue-magenta, and magenta-red.

[0054] With the above arrangement, each of the six inter-hue areas can be adjusted by varying the coefficients for the second comparison-result data without influencing other inter-hue areas.

[0055] It may be so configured that

said coefficient generating means generates specified matrix coefficients Eij (i = to 3, j = 1 to 3) based on a formula (5) below:

$$(Eij) = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \qquad \ldots(5)$$

and generates the matrix coefficients Fij (i = 1 to 3, j = 1 to 18, or j = 1 to 19) such that, of the coefficients Fij, the coefficients for said calculation result data are set to zero, and other coefficients are set to specified values.

[0056] With the above arrangement, it is not necessary to carry out the calculation to determine the calculation-result data for which the coefficients are zero, and yet the hue of the six hues of red, blue, green yellow, cyan, and magenta, or the inter-hue area in question can be linearly adjusted, without influencing other hues or inter-hue areas.

[0057] It may be so configured that

said calculating means for calculating a maximum value β and a maximum value α of said first set of three color data calculates a maximum value β and a minimum value α using said first set of three color data, and generates an identification code indicating the hue data which is of a value zero, and

said second calculation means performs arithmetic operation on said hue data based on the identification code outputted from said first calculation means,

said coefficient generating means generates said matrix coefficients based on the identification code outputted from said first calculation means, and

said matrix calculator performs matrix calculation using the coefficient from said coefficient generating means to produce second set of three color data based on the identification code outputted from said first calculation means.

[0058] With the above arrangement, the number of steps of second calculation means for performing the matrix calculation can be reduced.

[0059] According to another aspect of the invention, there is provided a color conversion method of performing pixel-by-pixel color conversion from a first set of three color data representing red, green and blue, or cyan, magenta and yellow, into a second set of three color data representing red, green and blue, or cyan, magenta, and yellow, said method comprising the steps of:

(a) calculating a minimum value α and a maximum value β of said first set of three color data for each pixel;
(b) calculating hue data r, g, b, y, m and c based on said first set of three color data, and said minimum and maximum values α and β obtained at said step (a);
(c) generating first comparison-result data based on the hue data obtained at said step (b);
(d) for generating second comparison-result data based on said first comparison-result data;
(e) performing calculation using the hue data obtained at said step (b) to produce calculation result data;
(f) generating specified matrix coefficients for the hue data, the calculation result data, the first comparison-result data and the second comparison-result data; and
(g) calculating, responsive to said hue data, said first comparison-result data, said second comparison-result data, said calculation result data, and the coefficients from said coefficient generating means, said second set of three color data,

said step (g) comprising the step of performing matrix calculation on at least said hue data, said first comparison-result data, said second comparison-result data, said calculation result data, and the coefficients obtained at said step (f).

[0060] It may be so configured that said step (g) comprises the steps of:

(g1) performing said matrix calculation on said hue data, said first comparison-result data, said second comparison-result data, said calculation result data, and the coefficients obtained at said step (f), and
(g2) adding said minimum value α from said first calculation means to the results of said matrix calculation.

[0061] It may be so configured that said step (g) comprises the step of performing said matrix calculation on said hue data, said first comparison-result data, said second comparison-result data, said calculation result data, the coefficients obtained at said step (f), and said minimum value α obtained at said step (a).

BRIEF DESCRIPTION OF THE DRAWINGS

[0062] In the accompanying drawings:-

Fig. 1 is a block diagram showing an example of configuration of a color conversion device of Embodiment 1 of the present invention;
Fig. 2 is a block diagram showing an example of configuration of a polynomial calculator included in the color conversion device of Embodiment 1;
Fig. 3 is a table showing an example of the relationship between an identification code S1, and the maximum and minimum values β and α, and hue data whose value is zero, in the color conversion device of Embodiment 1;
Fig. 4 is a table showing the operation of a zero remover of the polynomial calculator in the color conversion device of Embodiment 1;
Fig. 5 is a block diagram showing an example of configuration of a matrix calculator included in the color conversion device of Embodiment 1;
Fig. 6A to Fig. 6F are diagrams schematically showing the relationship between six six hues and hue data;
Fig. 7A to Fig. 7F are diagrams schematically showing the relationship between six hues and product terms in the color conversion device of Embodiment 1;
Fig. 8A to Fig. 8F are diagrams schematically showing the relationship between six hues and first comparison-result data in the color conversion device of Embodiment 1;
Fig. 9A to Fig. 9F are diagrams schematically showing the relationship between six inter-hue areas and second comparison-result data in the color conversion device of Embodiment 1;
Fig. 10A to Fig. 10F are diagrams schematically showing how the range of each inter-hue area is changed with the change of the coefficients multiplied at the polynomial calculator is changed;
Fig. 11A and Fig. 11B are tables showing the relationship between respective hues or inter-hue areas, and effective calculation terms or data which relate to and are effective for each hue or inter-hue area;
Fig. 12 is a block diagram showing an example of configuration of a color conversion device of Embodiment 2 of the present invention;
Fig. 13 is a block diagram showing an example of configuration of Embodiment 3 of the present invention;
Fig. 14 is a block diagram showing part of an example of configuration of a matrix calculator included in the color conversion device of Embodiment 3;
Fig. 15 is a block diagram showing an example of configuration of a color conversion device of Embodiment 4 of the present invention;
Fig. 16 is an xy chromaticity diagram illustrating the gamut of the color reproduction of the input color signals and

the gamut of a desired color reproduction, for explaining the operation of Embodiment 1;
Fig. 17 is an xy chromaticity diagram illustrating the gamut of the color reproduction obtained by adjusting the coefficients for the first comparison-result data, together with the gamut of the desired color reproduction, for explaining the operation of Embodiment 1;
Fig. 18 is an xy chromaticity diagram for explaining the gamut of the color reproduction obtained by adjusting the coefficients for the first and second comparison-result data, together with the gamut of the desired color reproduction, for explaining the operation of Embodiment 1;
Fig. 19 is a block diagram showing an example of configuration of a conventional color conversion device;
Fig. 20A to Fig. 20F are diagrams schematically showing the relationship between six hues and hue data in the conventional color conversion device; and
Fig. 21A to Fig. 21F are diagrams schematically showing the relationship between six hues and calculation terms in a matrix calculator included in the conventional color conversion device.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0063] Next, the preferred embodiments of the present invention will be described in detail with reference to the accompanying drawings.

Embodiment 1

[0064] Fig. 1 is a block diagram showing an example of configuration of a color conversion device of Embodiment 1 of the present invention. In the drawing, a minimum and maximum calculator 1 calculates a maximum value β and a minimum value α of the inputted image data R, G and B, which are represented by Ri, Gi and Bi, and generates and outputs an identification code S1 for indicating, among the six hue data, data which are zero, as will be better understood from the following description. A hue data calculator 2 calculates hue data r, g, b, y, m and c from the image data R, G and B and the outputs from the minimum and maximum calculator. Reference numerals 3 denotes a polynomial calculator; 4 denotes a matrix calculator; 5 denotes a coefficient generator; and 6 denotes a synthesizer.
[0065] Fig. 2 is a block diagram showing an example of configuration of the polynomial calculator 3. In Fig. 2, a zero remover 7 removes, from the inputted hue data, data which are of value zero. Reference numerals 8a and 8b denote multipliers. Minimum selectors 9a, 9b and 9c select and output the minimum of the input data. A calculation coefficient generator 11 generates and outputs calculation coefficients based on the identification code S1 from the minimum and maximum calculator 1. Arithmetic units 10a and 10b perform multiplication between the calculation coefficients represented by the outputs of the calculation coefficient generator 11 and the outputs from the minimum selectors 9a and 9b.
[0066] Next, the operation will be described. The inputted image data Ri, Gi and Bi are sent to the minimum and maximum calculator 1 and the hue data calculator 2. The minimum and maximum calculator 1 calculates and outputs a maximum value β and a minimum value α of the inputted image data Ri, Gi and Bi, and also generates and outputs an identification code S1 for indicating, among the six hue data, data data which are zero.
[0067] The hue data calculator 2 receives the image data Ri, Gi and Bi and the maximum and minimum values β and α from the minimum and maximum calculator 1, performs subtraction of

$$r = Ri - \alpha ,$$

$$g = Gi - \alpha ,$$

$$b = Bi - \alpha ,$$

$$y = \beta - Bi,$$

$$m = \beta - Gi$$

and

$$c = \beta - Ri,$$

and outputs six hue data r, g, b, y, m and c thus obtained.

[0068] The maximum and minimum values β and α calculated by the minimum and maximum calculator 1 are respectively represented as follows:

$$\beta = MAX (Ri, Gi, Bi)$$

$$\alpha = MIN (Ri, Gi, Bi)$$

Since the six hue data r, g, b, y, m and c calculated by the hue data calculator 2 are obtained by the subtraction of

$$r = Ri - \alpha,$$

$$g = Gi - \alpha,$$

$$b = Bi - \alpha,$$

$$y = \beta - Bi,$$

$$m = \beta - Gi$$

and

$$c = \beta - Ri,$$

there is a characteristic that at least two among these six hue data are of a value zero. For example, if a maximum value β is Ri and a minimum value α is Gi (β = Ri, and α = Gi), g = 0 and c = 0. If a maximum value β is Ri and a minimum value α is Bi (β = Ri, and α = Bi), b = 0 and c = 0. In other words, in accordance with a combination of Ri, Gi and Bi which are the largest and the smallest, respectively, one of r, g and b, and one of y, m and c, i. e., in total two of them have a value zero.

[0069] Thus, in the foregoing minimum and maximum calculator 1, identification code S1 for indicating, among the six hue data which are zero are generated and outputted. The identification code S1 can assume one of the six values, depending on which of Ri, Gi and Bi are of the maximum and minimum values β and α. Fig. 3 shows a relationship between the values of the identification code S1 and the maximum and minimum values β and α of Ri, Gi and Bi and hue data which has a value zero. In the drawing, the values of the identification code S1 represent just an example, and the values may be other than those shown in.

[0070] Then, the six hue data r, g, b, y, m and c outputted from the hue data calculator 2 are sent to the polynomial calculator 3, and the hue data r, g and b are also sent to the matrix calculator 4. The polynomial calculator 3 also receives the identification code S1 outputted from the minimum and maximum calculator 1, and performs calculation by selecting, from the hue data r, g and b, two data Q1 and Q2 which are not zero, and from the hue data y, m and c, two data P1 and P2 which are not of a value zero. Next, this operation will be described by referring to Fig. 2.

[0071] The hue data from the hue data calculator 2 and the identification code S1 from the minimum and maximum calculator 1 are inputted to the zero remover 7 in the polynomial calculator 3. The zero remover 7 outputs, based on the identification code S1, the two data Q1 and Q2 which are not of a value zero, among the hue data r, g and b and the two data P1 and P2 which are not of a value zero, among the hue data y, m and c. For instance, Q1, Q2, P1 and P2 are determined as shown in Fig. 4, and then outputted. If, for example, the identification code S1 is of a value zero, Q1 and Q2 are obtained from the hue data r and b, and P1 and P2 are obtained from the hue data y and m, so the outputs are given by Q1 = r, Q2 = b, P1 = m and P2 = y. As in the case of Fig. 3, the values of the identification code

S1 in Fig. 4 represent just an example, and may be other than those shown in Fig. 4.

[0072] The data Q1 and Q2 outputted from the zero remover 7 are inputted to the multiplier 8a, which calculates and outputs the product T3 = Q1*Q2. The data P1 and P2 outputted from the zero remover 7 are inputted to the multiplier 8b, which calculates and outputs the product T1 = P1*P2.

[0073] The minimum selector 9a selects and outputs the minimum value T4 = min (Q1, Q2) among the output data Q1 and Q2 from the zero remover 7. The minimum selector 9b selects and outputs the minimum value T2 = min (P1, P2) among the output data P1 and P2 from the zero remover 7. The outputs of the minimum selectors 9a and 9b are the first comparison-result data.

[0074] The identification code S1 is inputted from the minimum and maximum calculator 1 to the calculation coefficient generator 11, which generates signals indicating calculation coefficients aq and ap based on the identification code S1, and the coefficient aq is supplied to the arithmetic unit 10a, and the coefficient ap is supplied to the arithmetic unit 10b. These calculation coefficients aq and ap are used for multiplication with the comparison-result data T4 and T2, and each of the calculation coefficients aq and ap can assume one of the six values, corresponding to the value of the identification code S1 shown in Fig. 4. The arithmetic unit 10a receives the comparison-result data T4 from the minimum selector 9a, performs multiplication of aq*T4, and sends the result to the minimum selector 9c. The arithmetic unit 10b receives the comparison-result data T2 from the minimum selector 7, performs multiplication of ap*T2, and sends the result to the minimum selector 9c.

[0075] The minimum selector 9c selects and outputs the minimum value T5 = min (aq*T2, ap*T4) of the outputs the arithmetic units 10a and 10b. The output of the minimum value selector 9c is a second comparison-result data.

[0076] The polynomial data T1, T2, T3, T4 and T5 outputted from the polynomial calculator 3 are supplied to the matrix calculator 4.

[0077] The coefficient generator 5 shown in Fig. 1 generates calculation coefficients U (Fij) and fixed coefficients U (Eij) for the polynomial data based on the identification code S1, and sends the same to the matrix calculator 4.

[0078] The matrix calculator 4 receives the hue data r, g and b from the hue data calculator 2, the polynomial data T1 to T5 from the polynomial calculator 3 and the coefficients U from the coefficient generator 5, and outputs the results of calculation according to the following formula (6) as image data R1, G1 and B1.

$$\begin{bmatrix} R1 \\ G1 \\ B1 \end{bmatrix} = (Eij) \begin{bmatrix} r \\ g \\ b \end{bmatrix} + (Fij) \begin{bmatrix} T1 \\ T2 \\ T3 \\ T4 \\ T5 \end{bmatrix} \qquad \ldots(6)$$

[0079] For (Eij), i = 1 to 3 and j = 1 to 3, and for (Fij), i = 1 to 3 and j = 1 to 5.

[0080] Fig. 5, which is a block diagram, shows an example of configuration of part of the matrix calculator 4. Specifically, it shows how R1 is calculated and outputted. As shown in Fig. 5, the matrix calculator 4 includes multipliers 12a to 12f, and adders 13a to 13e interconnected as illustrated.

[0081] Next, the operation of the matrix calculator 4 of Fig. 5 will be described. The multipliers 12a to 12f receive the hue data r, the polynomial data T1 to T5 from the polynomial calculator 3 and the coefficients U (Eij) and U (Fij) from the coefficient generator 5, and then output the products thereof. The adders 13a and 13b receive the products outputted from the multipliers 12b to 12e, add the inputted data and outputs the sums thereof. The adder 13c adds the data from the adders 13a and 13b, and the adder 13d adds the output from the adder 13c and the product outputted from the multiplier 12f. The adder 13e adds the output from the adder 13d and the output from the multiplier 12a, and outputs the sum total thereof as image data R2. In the example of configuration shown in Fig. 5, if the hue data r is replaced by the hue data g or b, and coefficients suitable for the respective terms (data) T1 to T5 are used in substitution, image data G2 or B2 can be calculated.

[0082] The image data R2, G2 and B2 are added to the results of separate matrix calculation using the hue data r, g and b and the coefficients (Eij), as represented by the first term in the formula (6), to result in the image data R1, G1 and B1.

[0083] The part of the coefficients (Eij) and (Fij) corresponding to the hue data r, g and b are used. In other words, if three configurations, each similar to that of Fig. 5, are used in parallel for the hue data r, g and b, matrix calculation can be performed at a higher speed.

[0084] The synthesizer 6 receives the image data R1, G1 and B1 from the matrix calculator 4 and the minimum value α outputted from the minimum and maximum calculator 1 representing the achromatic data, performs addition, and outputs image data R, G and B. The equation used for obtaining the image data color-converted by the color-conversion method of Fig. 1 is therefore given by the following formula (1).

$$\begin{bmatrix} R \\ G \\ B \end{bmatrix} = (Eij) \begin{bmatrix} r \\ g \\ b \end{bmatrix} + (Fij) \begin{bmatrix} c*m \\ m*y \\ y*c \\ r*g \\ g*b \\ b*r \\ h1r \\ h1g \\ h1b \\ h1c \\ h1m \\ h1y \\ h2ry \\ h2rm \\ h2gy \\ h2gc \\ h2bm \\ h2bc \end{bmatrix} + \begin{bmatrix} \alpha \\ \alpha \\ \alpha \end{bmatrix} \quad \ldots(1)$$

[0085] Here, for (Eij), i = 1 to 3 and j = 1 to 3, and for (Fij), i = 1 to 3 and j = 1 to 18, and

$$h1r = \min(m, y),$$

$$h1g = \min(y, c),$$

$$h1b = \min(c, m),$$

$$h1c = \min(g, b),$$

$$h1m = \min(b, r),$$

$$h1y = \min(r, g),$$

$$h2ry = \min(aq1*h1y, ap1*h1r),$$

$$h2rm = \min(aq2*h1m, ap2*h1r),$$

$$h2gy = \min(aq3*h1y, ap3*h1g),$$

$$h2gc = \min(aq4*h1c, ap4*h1g),$$

$$h2bm = \min(aq5*h1m, ap5*h1b),$$

and

$$h2bc = \min (aq6*h1c, ap6*h1b),$$

and aq1 to aq6 and ap1 to ap6 indicate calculation coefficients generated by the calculation coefficient generator 11 of Fig. 2.

[0086] The difference between the number of calculation terms in the formula (1) and the number of calculation terms in Fig. 1 is that Fig. 1 shows a method of calculation for each pixel excluding the calculation terms which are of a value zero, while the formula (1) represents a general formula for a set of pixels. In other words, eighteen polynomial data for one pixel of the formula (1) can be reduced to five effective data, and this reduction is achieved by exploiting a characteristic of the hue data.

[0087] The combination of effective data is changed according to image data of the target pixel. For all image data, all the polynomial data can be effective.

[0088] Fig. 6A to Fig. 6F schematically show relations between the six hues and the hue data y, m, c, r, g and b. Each hue data relates to, i.e., extends to cover the range of three hues.

[0089] Fig. 7A to Fig. 7F schematically show relations between the six hues and the product terms y*m, r*g, c*y, g*b, m*c and b*r, and it can be understood that each product term is a second-order term for a specified hue. For example, if W is a constant, since r = W and g = b = 0 hold for red, y = m = W and c = 0 are obtained. Accordingly, y*m = W*W is realized, and this term is a second-order term. The other five terms are all zero. In other words, only y*m is an effective second-order term for red. Similarly, c*y is the only effective term for green; m*c for blue; g*b for cyan; b*r for magenta; and r*g for yellow.

[0090] Each of the foregoing formulae (6) and (1) includes a first comparison-result data effective only for one hue. The first comparison-result data are:

$$h1r = \min (y, m),$$

$$h1y = \min (r, g)$$

$$h1g = \min (c, y),$$

$$h1c = \min (g, b),$$

$$h1b = \min (m, c),$$

and

$$h1m = \min (b, r).$$

[0091] Fig. 8A to Fig. 8F schematically show relations between the six hues and first comparison-result data h1r, h1y,h1g, h1c, h1b, and h1m. It is seen that each of the first comparison-result data relates to only one specific hue.

[0092] The six first comparison-result data has the nature of a first-order term. For instance, if W is a constant, for red, r = W, g = b = 0, so that y = m = W, and c = 0. As a result, min (y, m) = W has a first-order value. The other five first comparison-result data are all of a value zero. That is, for red, h1r = min (y, m) alone is the only effective first comparison-result data. Similarly, h1g = min (c, y) is the only effective first comparison-result data for green; h1b = min (m, c) for blue; h1c = min (g, b) for cyan; h1m = min (b, r) for magenta; and h1y = min (r, g) for yellow.

[0093] Next, a difference between the first-order and second-order terms will be described. As described above, for red, if W is a constant, y*m = W*W is realized, and the other product terms are all zero. Here, since the constant W indicates the magnitudes of the hue signals y and m, the magnitude of the constant W depends on the color brightness or chroma. With y*m = W*W, the product term y*m is a second-order function for chroma. The other product terms are also second-order functions for chroma regarding the hues to which these terms are effective. Accordingly, influence given by each product term to color reproduction is increased in a second-order manner as chroma is increased. In other words, the product term is a second-order term which serves as a second-order adjustment term for chroma in color reproduction.

[0094] On the other hand, for red, if W is a constant, h1r = min (m, m) = W is realized, and the other first comparison-result data are all zero. Here, the magnitude of the constant W depends of color brightness or chroma. With h1r = min (y, m) = W, the comparison-result data h1r = min (y, m) is a first-order function for chroma. The other first comparison-result data are also first-order functions for chroma regarding the hues to which these terms are effective. Accordingly, the influence given by each first comparison-result data to color reproduction is a first-order function for chroma. In other words, the first comparison-result data is a first-order term which serves as a first-order adjustment term for chroma in color reproduction.

[0095] Fig. 9A to Fig. 9F schematically show relations between the six hues and second comparison-result data:

$$h2ry = \min (h1y, h1r),$$

$$h2gy = \min (h1y, h1g),$$

$$h2gc = \min (h1c, h1g),$$

$$h2bc = \min (h1c, h1b),$$

$$h2bm = \min (h1m, h1b),$$

and

$$h2rm = \min (h1m, h1r).$$

[0096] This is the case in which the coefficients aq1 to aq6 and ap1 to ap6 in

$$h2ry = \min (aq1*h1y, ap1*h1r),$$

$$h2rm = \min (aq2*h1m, ap2*h1r),$$

$$h2gy = \min (aq3*h1y, ap3*h1g),$$

$$h2gc = \min (aq4*h1c, ap4*h1g),$$

$$h2bm = \min (aq5*h1m, ap5*h1b),$$

and

$$h2bc = \min (aq6*h1c, ap6*h1b),$$

in the formula (1) above are all of a value "1".

[0097] It can be understood from Fig. 9A to Fig. 9F, that each of the second comparison-result data relates to changes in the six inter-hue areas of red-yellow, yellow-green, green-cyan, cyan-blue, blue-magenta, and magenta-red. In other words, for red-yellow, b = c = 0, and the five terms other than h2ry = min (hly, hlr) = min (min (r, g), min (y, m)) are all zero. Accordingly, only h2ry is an effective second comparison-result data. Similarly, only h2gy is an effective second comparison-result data for yellow-green; h2gc for green-cyan; h2bc for cyan-blue: h2bm for blue-magenta; and h2rm for magenta-red.

[0098] Moreover, the range of the inter-hue area to which each of the second comparison-result data relates is half that of the range of the hue to which each of the first comparison-result data relates.

[0099] Fig. 10A to Fig. 10F schematically show how the range of the six inter-hue area to which each of the second comparison-result data relate is changed when the coefficients aq1 to aq6 and ap1 to ap6 used for determination of h2ry, h2rm, h2gy, h2gc, h2bm and h2bc according to the foregoing formulae (6) and (1) are changed. The broken lines a1 to a6 shows the characteristics when aq1 to aq6 assume values larger than ap1 to ap6. The broken lines b1 to b6 shows the characteristics when ap1 to ap6 assume values larger than aq1 to aq6.

[0100] Specifically, for inter-hue area red-yellow, only h2ry = min (aq1*h1y, ap1*h1r) is an effective second comparison-result data. If, for example, the ratio between aq1 and ap1 is 2:1, the peak value of the second comparison-result data is shifted toward red, as indicated by the broken line a1 in Fig. 10A, and thus it can be made an effective comparison-result data for an area closer to red in the inter-hue area of red-yellow. On the other hand, for example if the ratio between aq1 and ap1 is 1:2, the relationship is like that indicated by the broken line b1 in Fig. 10A, the peak value of the second comparison-result data is shifted toward yellow, and thus it can be made an effective comparison-result data for an area closer to yellow in the inter-hue area of red-yellow. Similarly, by respectively changing:

aq3 and ap3 in h2gy for yellow-green,
aq4 and ap4 in h2gc for green-cyan,
aq6 and ap6 in h2bc for cyan-blue,
aq5 and ap5 in h2bm for blue-magenta and
aq2 and ap2 in h2rm for magenta-red,

in the area for which each second comparison-result data is most effective can be changed.

[0101] Fig. 11A to Fig. 11B respectively show relations between the six hues and inter-hue areas and effective calculation terms. Thus, if the coefficient generator 5 changes coefficients for a calculation term effective for a hue or an inter-hue area to be adjusted, only the target hue can be adjusted, and the inter-hue areas can also be adjusted. Further, if coefficients generated by the calculation coefficient generator 11 in the polynomial calculator 3 are changed, part of the inter-hue area where a calculation term in the inter-hue area is most effective can be changed without giving any influence to the other hues.

[0102] Next, an example of coefficients generated by the coefficient generator 5 of Embodiment 1 described above with reference to Fig. 1 will be described. The following formula (5) shows an example of coefficients U (Eij) generated by the coefficient generator 5.

$$(Eij) = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \qquad \ldots(5)$$

[0103] If the coefficients U (Eij) in the foregoing formula are all zero this represents the case where color conversion is not executed. The following formula (7) shows the case where, of the coefficients U (Fij), the coefficients for second-order calculation terms which are product terms are all zero, and coefficients for first comparison-result data and second comparison-result data, both of which are first-order calculation terms, are represented by, for example Ar1 to Ar3, Ay1 to Ay3, Ag1 to Ag3, Ac1 to Ac3, Ab1 to Ab3, Am1 to Am3, Ary1 to Ary3, Agy1 to Agy3, Agc1 to Agc3, Abc1 to Abc3, Abm1 to Abm3 and Arm1 to Arm3.

$$(Fij) = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & Ar1 & Ag1 & Ab1 & Ac1 & Am1 & Ay1 & Ary1 & Arm1 & Agy1 & Agc1 & Abm1 & Abc1 \\ 0 & 0 & 0 & 0 & 0 & 0 & Ar2 & Ag2 & Ab2 & Ac2 & Am2 & Ay2 & Ary2 & Arm2 & Agy2 & Agc2 & Abm2 & Abc2 \\ 0 & 0 & 0 & 0 & 0 & 0 & Ar3 & Ag3 & Ab3 & Ac3 & Am3 & Ay3 & Ary3 & Arm3 & Agy3 & Agc3 & Abm3 & Abc3 \end{bmatrix} \qquad \ldots(7)$$

[0104] In the foregoing, adjustment is performed by using the first comparison-result data and second comparison-result data, both of which are first-order calculation terms. Accordingly, only a hue or an inter-hue area can be linearly adjusted and, if coefficients relating to a first-order calculation term for a hue or an inter-hue area to be adjusted are set to be values other than zero and the other coefficients are made to be zero, only the target hue or inter-hue area can be adjusted. For example, if coefficients Ar1 to Ar3 relating to hlr relating to red are set, the red hue is changed, and to vary the proportion between red and yellow, the coefficients Ary1 to Ary3 relating to h2ry are used.

[0105] In the arrangement described above, the correction is made using both the first comparison-result data and the second comparison-result data, which are first-order terms. The second-order terms may be dispensed with. That is, the multipliers 8a and 8b in the polynomial calculator 3 shown in Fig. 2, and the multipliers 12a and 12b, and the adders 13a and 13b the matrix calculator 4 shown in Fig. 5 may be omitted.

[0106] Furthermore, if, in the polynomial calculator 3, the values of calculation coefficients aq1 to aq6 and ap1 to ap6 in

$$h2ry = \min (aq1*h1y, ap1*h1r),$$

$$h2rm = \min (aq2*h1m, ap2*h1r),$$

$$h2gy = \min (aq3*h1y, ap3*h1g),$$

$$h2gc = \min (aq4*h1c, ap4*h1g),$$

$$h2bm = \min (aq5*h1m, ap5*h1b),$$

and

$$h2bc = \min (aq6*h1c, ap6*h1b)$$

are changed so as to assume integral values of 1, 2, 4, 8,..., i.e., 2^n (where n is an integer), multiplication can be achieved in the arithmetic units 10a and 10b by bit shifting.

[0107] As apparent from the foregoing, by changing the coefficients of the product terms and first and second comparison-result data relating to specific hue or inter-hue area, the coefficients U (Fij) can be independently varied, and thus the six inter-hue areas can also be varied. Each of the foregoing product terms is a second-order calculation for chroma, and each of the first and second comparison-result data is a first-order calculation for chroma. Accordingly, by using the product terms, and the first and second comparison-result data, the non-linearity of an image-printing or the like can be varied for chroma. Provided therefore is a color conversion device or a color conversion method, which is capable of flexibly changing a conversion characteristic and eliminates the necessity of a large-capacity memory.

[0108] Further description on the operation of the color conversion device using the coefficients represented by the formulae (5) and (7) will be given. Fig. 16 to Fig. 18 show an xy chromaticity diagram showing the operation of the color conversion device of Embodiment 1. Fig. 16 shows the gamut of color reproduction (reproducible colors) of the input color signals Ri, Gi, and Bi, and the gamut of the desired color reproduction. In Fig. 16 to Fig. 18, the dotted line 21 represents the gamut of the desired color reproduction. In Fig. 16, the triangle of the solid line 22 represents the gamut of color reproduction of the input color signals. Here, the input color signals may be those for a certain type of image reproducing device, such as a display device, e.g., a CRT monitor. The "desired color reproduction" may be the color reproduction by another type of display device, or theoretical or imaginary color reproduction.

[0109] The directions of lines extending from the center of each triangle to the vertexes and points on the sides of the triangle represent respective hues.

[0110] In the example of Fig. 16, there are differences between the color reproduction of the input color signals and the desired color reproduction with regard to the directions of the lines extending from the center of the triangle to the vertexes and points on the sides. This means that the hues of the reproduced colors are different.

[0111] The color conversion device of Embodiment 1 of the invention uses the first comparison-result data effective for each of the six hues, and the second comparison-result data effective for each of the inter-hue areas.

[0112] In Fig. 17, the solid line 23 represents the gamut of the color reproduction after the adjustment of the coefficients for the first comparison-result data, while the broken line 24 represents the gamut of the color reproduction without the adjustment of the coefficients. As will be seen, the hues of the color reproduction as represented by the solid line 23 and the hues of the desired color reproduction as represented by the dotted line 21 coincide with each other. The coincidence is achieved by adjusting the coefficients for the first comparison-result data. However, it is noted that the gamut of the color reproduction as represented by the solid line 23 is narrower than the gamut of the color reproduction as represented by the broken line 24 (without the adjustment of the coefficients).

[0113] Fig. 18 shows the gamut 25 of the color reproduction obtained when both the coefficients for the first comparison-result data and the coefficients for the second comparison-result data are adjusted By adjusting both the coefficients for the first and second comparison-result data, the hues of the color reproduction as represented by the line 25 coincides with the hues of the desired color reproduction, and the gamut 25 of the color reproduction obtained when both the coefficients for the first and second comparison-result data are identical to the gamut (22 in 16) of the color reproduction obtained when the coefficients for the first and second comparison-result data are not adjusted. That is, in the color conversion device according to Embodiment 1 of the invention, by adjusting the coefficients for the first and second comparison-result data, the hues can be adjusted without narrowing the gamut of the color reproduction.

[0114] In Embodiment 1 described above, the hue data r, g, b, y, m and c, and the maximum and minimum values β and α were calculated based on the inputted image data Ri, Gi and Bi so as to obtain the calculation terms for the respective hues, and after the matrix calculation, the image data R, G and B were obtained. However, after the outputted image data are obtained, the data Ri, Gi and Bi may be converted into complementary color data C, M and Y, by determining 1's complement. In this case, the same effects will be realized.

[0115] Furthermore, in Embodiment 1 described above, the processing was performed by the hardware configuration of Fig. 1. Needless to say, the same processing can be performed by software in the color conversion device, and in this case, the same effects as those of Embodiment 1 will be provided.

Embodiment 2

[0116] In Embodiment 1, the hue data r, g, b, y, m and c, and the maximum and minimum values β and α were calculated based on the inputted image data of red, green and blue so as to obtain the calculation terms for the respective hues, and after the matrix calculation, the image data red, green and blue were obtained. But the image data of red, green and blue may first be converted into complementary color data of cyan, magenta and yellow, by determining 1's complement of the input image data, and then color conversion may be executed by inputting the complementary color data of cyan, magenta and yellow.

[0117] Fig. 12 is a block diagram showing an example of configuration of a color conversion device of Embodiment 2 of the present invention. In describing Embodiment 2, the inputted image data of red, green and blue are represented by R, G and B. Reference numerals 3 to 6 denote the same members as those described with reference to Fig. 1 in connection with Embodiment 1. Reference numeral 14 denotes a complement calculator; 1b, a minimum and maximum calculator for generating maximum and minimum values β and α of complementary color data and an identification code for indicating, among the six hue data, data which are zero; and 2b, a hue data calculator for calculating hue data r, g, b, y, m and c based on complementary color data C, M and Y from the complement calculator 14 and outputs from the minimum and maximum calculator 1b.

[0118] Next, the operation will be described. The complement calculator 14 receives the image data R, G and B, and outputs complementary color data Ci, Mi and Yi obtained by determining 1's complements. The minimum and maximum calculator 1b outputs the maximum and minimum values β and α of each of these complementary color data and the identification code S1.

[0119] Then, the hue data calculator 2b receives the complementary color data Ci, Mi and Yi and the maximum and minimum values β and α from the minimum and maximum calculator 1b, performs subtraction of

$$r = \beta - Ci,$$

$$g = \beta - Mi,$$

$$b = \beta - Yi,$$

$$y = Yi - \alpha,$$

$$m = Mi - \alpha,$$

and

$$c = Ci - \alpha ,$$

and outputs six hue data r, g, b, y, m and c. Here, at least two among these six hue data are zero. The identification code S1 outputted from the minimum and maximum calculator 1b is used for specifying, among the six hue data, data which is zero. The value of the identification code S1 depends on which of Ci, Mi and Yi the maximum and minimum values β and α are. Relations between the data among the six hue data which are zero, and the values of the identification code S1 are the same as those in Embodiment 1, and thus further explanation will be omitted.

[0120] Then, the six hue data r, g, b, y, m and c outputted from the hue data calculator 2b are sent to the polynomial calculator 3, and the hue data c, m and y are also sent to the matrix calculator 4. The polynomial calculator 3 also receives the identification code S1 outputted from the minimum and maximum calculator 1b, and performs calculation by selecting, from the hue data, two data Q1 and Q2 which are not zero, and from the hue data y, m and c, two data P1 and P2 which are not of a value zero. This operation is identical to that described with reference to Fig. 2 in connection with Embodiment 1, so that detailed description thereof is omitted.

[0121] The output of the polynomial calculator 3 is supplied to the matrix calculator 4, and the coefficient generator 5 generates the calculation coefficients U (Fij) and fixed coefficients U (Eij) for the polynomial data based on the identification code S1, and sends the same to the matrix calculator 4. The matrix calculator 4 receives the hue data c, m and y from the hue data calculator 2b, the polynomial data T1 to T5 from the polynomial calculator 3 and the coefficients U from the coefficient generator 5, and outputs the results of calculation according to the following formula (8) as image data C1, M1 and Y1.

$$\begin{bmatrix} C1 \\ M1 \\ Y1 \end{bmatrix} = (Eij) \begin{bmatrix} c \\ m \\ y \end{bmatrix} + (Fij) \begin{bmatrix} T1 \\ T2 \\ T3 \\ T4 \\ T5 \end{bmatrix} \qquad \ldots (8)$$

[0122] In the formula (8), for (Eij), i = 1 to 3 and j = 1 to 3, and for (Fij), i = 1 to 3 and j = 1 to 5.

[0123] The operation at the matrix calculator 4 is similar to that described with reference to Fig. 5 in connection with Embodiment 1, but the inputted hue data is c (or m, y) and C1 (or M1, Y1) is calculated and outputted. The detailed description thereof is therefore omitted.

[0124] The synthesizer 6 receives the image data C1, M1 and Y1 from the matrix calculator 4 and the minimum value α outputted from the minimum and maximum calculator 1b representing the achromatic data, performs addition, and outputs image data C, M and Y. The equation used for obtaining the image data color-converted by the color-conversion method of Fig. 12 is therefore given by the following formula (2).

$$\begin{bmatrix} C \\ M \\ Y \end{bmatrix} = (Eij) \begin{bmatrix} c \\ m \\ y \end{bmatrix} + (Fij) \begin{bmatrix} c*m \\ m*y \\ y*c \\ r*g \\ g*b \\ b*r \\ h1r \\ h1g \\ h1b \\ h1c \\ h1m \\ h1y \\ h2ry \\ h2rm \\ h2gy \\ h2gc \\ h2bm \\ h2bc \end{bmatrix} + \begin{bmatrix} \alpha \\ \alpha \\ \alpha \end{bmatrix} \qquad \ldots (2)$$

[0125] In the formula (2), for (Eij), i = 1 to 3 and j = 1 to 3, and for (Fij), i = 1 to 3 and j = 1 to 18, and

$$h1r = \min(m, y),$$

$$h1g = \min(y, c),$$

$$h1b = \min(c, m),$$

$$h1c = \min(g, b),$$

$$h1m = \min(b, r),$$

$$h1y = \min(r, g),$$

$$h2ry = \min(aq1*h1y, ap1*h1r),$$

$$h2rm = \min(aq2*h1m, ap2*h1r),$$

$$h2gy = \min(aq3*h1y, ap3*h1g),$$

$$h2gc = \min(aq4*h1c, ap4*h1g),$$

$$h2bm = \min(aq5*h1m, ap5*h1b),$$

and

$$h2bc = \min(aq6*h1c, ap6*h1b),$$

and aq1 to aq6 and ap1 to ap6 indicate calculation coefficients generated by the calculation coefficient generator 11 of Fig. 2.

[0126] The difference between the number of calculation terms in the formula (2) and the number of calculation terms in Fig. 12 is that Fig. 12 shows a method of calculation for each pixel excluding the calculation terms which are of a value zero, while the formula (2) represents a general formula for a set of pixels. In other words, eighteen polynomial data for one pixel of the formula (2) can be reduced to five effective data, and this reduction is achieved by exploiting a characteristic of the hue data.

[0127] The combination of effective data is changed according to image data of the target pixel. For all image data, all the polynomial data can be effective.

[0128] The calculation terms output from the polynomial calculator based on the formula (2) are identical to those of the formula (1) in Embodiment 1. Thus, relations between the six hues and inter-hue areas and effective calculation terms are the same as those shown in Fig. 11A and Fig. 11B. Therefore, as in Embodiment 1, in the coefficient generator 5, by changing the coefficients for an effective calculation term for a hue or for an inter-hue area to be adjusted, only the target hue can be adjusted.

In addition, by changing the coefficients in the calculation coefficient generator 11 in the polynomial calculator 3, part of the inter-hue area where the calculation term in the inter-hue area is effective can be changed without giving any influence to the other hues.

[0129] Here, an example of coefficients generated by the coefficient generator 5 of Embodiment 2 are the coefficients

U (Eij) of the formula (5), as in Embodiment 1. If the coefficients U (Fij) are all zero, color conversion is not executed. Also, if those of the coefficients U (Fij) of the formula (7) which relate to the second-order calculation terms which are product terms are all zero, and adjustment is performed based on the coefficients for the first and second comparison-result data, which are first-order calculation terms, a hue or an inter-hue area can be adjusted only linearly. By setting coefficients relating to a first-order calculation term for a hue or an inter-hue area to be changed and setting other coefficients to zero, only the target hue or inter-hue area can be adjusted.

[0130] As apparent from the foregoing, by changing the coefficients of the product terms and first comparison-result data relating to specific hues or inter-hue areas, it is possible to adjust only the target hue among the six hues of red, blue, green, yellow, cyan and magenta, without influencing other hues, and by changing the coefficients relating to the second comparison-result data based on the hue data, it is possible to vary the six inter-hue areas of red-yellow, yellow-green, green-cyan, cyan-blue, blue-magenta, and magenta-red. Each of the foregoing product terms is a second-order calculation for chroma, and each of the first and second comparison-result data is a first-order calculation for chroma. Accordingly, by using the product term and the first and second comparison-result data, the non-linearity of an image-printing or the like can be varied for chroma. Provided therefore is a color conversion device or a color conversion method, which is capable of flexibly changing a conversion characteristic and eliminates the necessity of a large-capacity memory.

[0131] Furthermore, in Embodiment 2 described above, the processing was performed by the hardware configuration of Fig. 12. Needless to say, the same processing can be performed by software in the color conversion device, and in this case, the same effects as those of Embodiment 2 will be provided.

Embodiment 3

[0132] In Embodiment 1, part of an example of configuration of the matrix calculator 4 is as shown in the block diagram of Fig. 5, and the hue data and the respective calculation terms and the minimum value α among the image data Ri, Gi and Bi which is achromatic data are added to output the image data R, G, B, as shown in the formula (1). It is possible to adopt a configuration shown in Fig. 13 in which coefficients for the minimum value α which is achromatic data are generated in the coefficient generator, to adjust the achromatic component.

[0133] Fig. 13 is a block diagram showing an example of configuration of a color conversion device of Embodiment 3 of the present invention. In the figure, reference numerals 1 to 3 denote members identical to those described with reference to Fig. 1 in connection with Embodiment 1. Reference numeral 4b denotes a matrix calculator, 5b denotes a coefficient generator.

[0134] The operation will next be described. The determination of the maximum value β, the minimum value α, and the identification code S1 from the inputted data at the minimum and maximum calculator 1, the calculation of the six hue data at the hue data calculator 2, and the determination of the calculation terms at the polynomial calculator 3 are identical to those of Embodiment 1, and detailed description thereof is therefore omitted.

[0135] The coefficient generator 5b in Fig. 13 generates the calculation coefficients U (Fij) and the fixed coefficients U (Eij) of the polynomial data based on the identification code S1 and sends them to the matrix calculator 4b. The matrix calculator 4b receives the hue data r, g, and b from the hue data calculator 2, the polynomial data T1 to T5 from the polynomial calculator 3, the minimum value α from the minimum and maximum calculator 1, and the coefficients U from the coefficient generator 5b, and performs calculation thereon. The equation used for the calculation is represented by the following formula (9), for adjusting the achromatic component as well.

$$\begin{bmatrix} R1 \\ G1 \\ B1 \end{bmatrix} = (Eij) \begin{bmatrix} r \\ g \\ b \end{bmatrix} + (Fij) \begin{bmatrix} T1 \\ T2 \\ T3 \\ T4 \\ T5 \\ \alpha \end{bmatrix} \quad \ldots (9)$$

[0136] In the formula (9), for (Eij), i = 1 to 3 and j = 1 to 3, and for (Fij), i = 1 to 3 and j = 1 to 6.

[0137] Fig. 14 is a block diagram showing an example of configuration of the matrix calculator 4b. In Fig. 14, reference numerals 12a to 12f and 13a to 13f denote members identical to those in the matrix calculator 4 of Embodiment 1. Reference numeral 12g denotes a multiplier receiving the minimum value α from the minimum and maximum calculator 1 indicating the achromatic component, and the coefficients U from the coefficient generator 5b, and performs multiplication thereon. Reference numeral 13f denotes an adder.

[0138] Next, the operation will be described. The multipliers 12a to 12f receives the hue data r, the polynomial data T1 to T5 from the polynomial calculator 3 and the coefficients U (Eij) and U (Fij) from the coefficient generator 5, and

then output the products thereof. The adders 13a to 13e add the products and sums. These operations are identical to those of the matrix calculator 4 in Embodiment 1. The multiplier 12g receives the minimum value α among the image data Ri, Gi and Bi, from the minimum and maximum calculator 1 which corresponds to the achromatic component, and the coefficients U (Fij) from the coefficient generator 5b, and performs multiplication, and outputs the product to the adder 13f, where the product is added to the output of the adder 13e, and the sum total is output as the image data R2. In the example of Fig. 14, if the hue data r is replaced by g or b, the image data G2 or B2 is calculated.

[0139] The image data R2, G2 and B2 are added to the results of separate matrix calculation using the hue data r, g and b and the coefficients (Eij), as represented by the first term in the formula (9), to result in the color-converted image data R, G and B.

[0140] The part of the coefficients (Eij) and (Fij) corresponding to the hue data r, g and b are used. In other words, if three configurations, each similar to that of Fig. 14, are used in parallel for the hue data r, g and b, matrix calculation can be performed at a higher speed.

[0141] The equation for determining the image data is represented by the following formula (3).

$$\begin{bmatrix} R \\ G \\ B \end{bmatrix} = (Eij) \begin{bmatrix} r \\ g \\ b \end{bmatrix} + (Fij) \begin{bmatrix} c*m \\ m*y \\ y*c \\ r*g \\ g*b \\ b*r \\ h1r \\ h1g \\ h1b \\ h1c \\ h1m \\ h1y \\ h2ry \\ h2rm \\ h2gy \\ h2gc \\ h2bm \\ h2bc \\ \alpha \end{bmatrix} \quad \ldots(3)$$

[0142] In the formula (3), for (Eij), i = 1 to 3 and j = 1 to 3, and for (Fij), i = 1 to 3 and j = 1 to 19.

[0143] The difference between the number of calculation terms in the formula (3) and the number of calculation terms in Fig. 13 is that, as in Embodiment 1, Fig. 13 shows a method of calculation for each pixel excluding the calculation terms which are of a value zero, while the formula (3) represents a general formula for a set of pixels. In other words, nineteen polynomial data for one pixel of the formula (3) can be reduced to six effective data, and this reduction is achieved by exploiting a characteristic of the hue data.

[0144] The combination of effective data is changed according to image data of the target pixel. For all image data, all the polynomial data can be effective.

[0145] If all the coefficients relating to the minimum value α are "1", the achromatic data is not converted, and will be of the same value as the achromatic data in the inputted data. If the coefficients used in the matrix calculation are changed, it is possible to choose between reddish black, bluish black, and the like, and the achromatic component can be adjusted.

[0146] As apparent from the foregoing, by changing the coefficients of the product terms and first comparison-result data relating to specific hues or inter-hue area, and the second comparison-result data relating to the inter-hue areas, it is possible to adjust only the target hue or inter-hue area among the six hues of red, blue, green, yellow, cyan and magenta, and the six inter-hue areas, without influencing other hues and inter-hue areas, and by changing the coefficients relating to the minimum value α which is the achromatic data, it is possible to adjust only the achromatic component without influencing the hue components, and choose between a standard black, reddish black, bluish black and the like.

[0147] In Embodiment 3 described above, the image data R, G, B are obtained after the matrix calculation. As an alternative, the output image data R, G, B are first obtained, and then converted to C, M, Y, by determining 1's com-

plement. If the coefficients used in the matrix calculation can be changed for the respective hues, the inter-hue areas, and the minimum value α which is achromatic data, effects similar to those discussed above can be obtained.

[0148] Furthermore, also in Embodiment 3, the above described processing can be performed by software in the color conversion device, as in Embodiment 1, and yet effects similar to those obtained by Embodiment 3 can be obtained.

Embodiment 4

[0149] Embodiment 2 was configured to add the hue data, the calculation terms, and the minimum value α which is achromatic data, as shown in the formula (2). As an alternative, the configuration may be such that coefficients for the minimum value α which is achromatic data is generated at the coefficient generator, as shown in Fig. 15, so that the achromatic component is thereby adjusted.

[0150] Fig. 15 is a block diagram showing an example of configuration of color conversion device according to Embodiment 4 of the invention. In the figure, reference numerals 14, 1b, 2b and 3 denote members identical to those described with reference to Fig. 12 in connection with Embodiment 2, and reference numerals 4b and 5b denote members identical to those described with reference to Fig. 13 in connection with Embodiment 3.

[0151] The operation will next be described. The image data R, G, B are input to the complement calculator 14 to obtain the complementary data Ci, Mi, Yi by the process of determining 1's complement. The determination of the maximum value β , the minimum value α and the identification code S1 at the minimum and maximum calculator 1b, the calculation of the six hue data at the hue data calculator 2b, and the determination of the calculation terms at the polynomial calculator 3 are identical to those in the case of the complementary data C, M, Y in Embodiment 2. The detailed description thereof are therefore omitted.

[0152] The coefficient generator 5b in Fig. 15 generates the calculation coefficients U (Fij) and the fixed coefficients U (Eij) of the polynomial data based on the identification code S1 and sends them to the matrix calculator 4b. The matrix calculator 4b receives the hue data c, m, and y from the hue data calculator 2b, the polynomial data T1 to T5 from the polynomial calculator 3, the minimum value α from the minimum and maximum calculator 1, and the coefficients U from the coefficient generator 5b, and performs calculation thereon. The equation used for the calculation is represented by the following formula (10), and the achromatic component is adjusted.

$$\begin{bmatrix} C1 \\ M1 \\ Y1 \end{bmatrix} = (Eij) \begin{bmatrix} c \\ m \\ y \end{bmatrix} + (Fij) \begin{bmatrix} T1 \\ T2 \\ T3 \\ T4 \\ T5 \\ \alpha \end{bmatrix} \quad \ldots(10)$$

[0153] In the formula (10), for (Eij), i = 1 to 3 and j = 1 to 3, and for (Fij), i = 1 to 3 and j = 1 to 6.

[0154] The operation at the matrix calculator 4b is similar to that described with reference to Fig. 14 in connection with Embodiment 3, but the inputted hue data is c (or m, y) and C (or M, Y) is calculated and outputted. The detailed description thereof is therefore omitted.

[0155] The equation for determining the image data is represented by the following formula (4).

$$\begin{bmatrix} C \\ M \\ Y \end{bmatrix} = (Eij) \begin{bmatrix} c \\ m \\ y \end{bmatrix} + (Fij) \begin{bmatrix} c*m \\ m*y \\ y*c \\ r*g \\ g*b \\ b*r \\ h1r \\ h1g \\ h1b \\ h1c \\ h1m \\ h1y \\ h2ry \\ h2rm \\ h2gy \\ h2gc \\ h2bm \\ h2bc \\ \alpha \end{bmatrix} \quad \ldots(4)$$

[0156] In the formula (4), for (Eij), i = 1 to 3 and j = 1 to 3, and for (Fij), i = 1 to 3 and j = 1 to 19.

[0157] The difference between the number of calculation terms in the formula (4) and the number of calculation terms in Fig. 15 is that, as in Embodiment 2, Fig. 15 shows a method of calculation for each pixel excluding the calculation terms which are of a value zero, while the formula (4) represents a general formula for a set of pixels. In other words, nineteen polynomial data for one pixel of the formula (4) can be reduced to six effective data, and this reduction is achieved by exploiting a characteristic of the hue data.

[0158] The combination of effective data is changed according to image data of the target pixel. For all image data, all the polynomial data can be effective.

[0159] If all the coefficients relating to the minimum value α are "1", the achromatic data is not converted, and will be of the same value as the achromatic data in the inputted data. If the coefficients used in the matrix calculation are changed, it is possible to choose between reddish black, bluish black, and the like, and the achromatic component can be adjusted.

[0160] As apparent from the foregoing, by changing the coefficients of the product terms and first comparison-result data relating to specific hues or inter-hue area, and the second comparison-result data relating to the inter-hue areas, it is possible to adjust only the target hue or inter-hue area among the six hues of red, blue, green, yellow, cyan and magenta, and the six inter-hue areas, without influencing other hues and inter-hue areas, and by changing the coefficients relating to the minimum value α which is the achromatic data, it is possible to adjust only the achromatic component without influencing the hue components, and choose between a standard black, reddish black, bluish black and the like.

[0161] Furthermore, also in Embodiment 4, the above described processing can be performed by software in the color conversion device, as in the above-described embodiments, and yet effects similar to those obtained by Embodiment 4 can be obtained.

Claims

1. A color conversion device for performing pixel-by-pixel color conversion from a first set of three color data representing red, green and blue, or cyan, magenta and yellow, into a second set of three color data representing red, green and blue, or cyan, magenta, and yellow, said device comprising:

   first calculation means (1) for calculating a minimum value α and a maximum value β of said first set of three color data for each pixel;
   hue data calculating means (2) for calculating hue data r, g, b, y, m and c based on said first set of three color data, and said minimum and maximum values α and β outputted from said calculating means;
   means (9a, 9b) for generating first comparison-result data based on the hue data outputted from said hue data calculating means;

means (10a, 10b, 9c) for generating second comparison-result data based on said first comparison-result data;
second calculation means (8a, 8b) for performing calculation using the hue data outputted from said hue data calculating means to produce calculation result data;
coefficient generating means (5) for generating specified matrix coefficients for the hue data, the calculation result data, the first comparison-result data and the second comparison-result data; and
third calculation means (4+6; 4b) responsive to said hue data, said first comparison-result data, said second comparison-result data, said calculation result data, and the coefficients from said coefficient generating means for calculating said second set of three color data, said means performing calculation including matrix calculation performed at least on said hue data, said first comparison-result data, said second comparison-result data, said calculation result data, and the coefficients from said coefficient generating means.

2. The color conversion device according to claim 1, wherein said third calculation means performs said matrix calculation on said hue data, said first comparison-result data, said second comparison-result data, said calculation result data, and the coefficients from said coefficient generating means. and further includes synthesizing means (6) for adding said minimum value α from said first calculation means to the results of said matrix calculation.

3. The color conversion device according to claim 1, wherein said third calculation means performs said matrix calculation on said hue data, said first comparison-result data, said second comparison-result data, said calculation result data, the coefficients from said coefficient generating means, and said minimum value α from said first calculation means.

4. The color conversion device according to claim 1, wherein

said first set of three color data represent red, green and blue,
said second set of three color data represent red, green and blue, and
said hue data calculation means calculates the hue data r, g, b, y, m, c by subtraction in accordance with:

$$r = Ri - \alpha ,$$

$$g = Gi - \alpha ,$$

$$b = Bi - \alpha ,$$

$$y = \beta - Bi,$$

$$m = \beta - Gi,$$

and

$$c = \beta - Ri,$$

wherein Ri, Gi and Bi represent said first set of three color data.

5. The color conversion device according to claim 1, wherein

said first set of three color data represent red, green and blue,
said second set of three color data represent cyan, magenta and yellow,
said device further comprises means for determining complement of said first set of three color data, and
said hue data calculation means calculates the hue data r, g, b, y, m, c by subtraction in accordance with:

$$r = \beta - Ci,$$

$$g = \beta - Mi,$$

$$b = \beta - Yi,$$

$$y = Yi - \alpha,$$

$$m = Mi - \alpha,$$

and

$$c = Ci - \alpha.$$

wherein Ci, Mi and Yi represent data produced by the determination of the complement said first set of three color data.

6. The color conversion device according to claim 1, wherein

said first comparison-result data generating means determines the comparison-result data among the hue data r, g and b, and the comparison-result data among the hue data y, m and c, and
said second comparison-result data generating means comprises multiplying means for multiplying the first comparison-result data outputted from said first comparison-result data generating means with specific calculation coefficients, and means for determining the comparison-result data based on the outputs of said multiplication means.

7. The color conversion device according to claim 1, wherein each of said first comparison-result data is determined from two of the hue data and is effective for only one of the six hues of red, green, blue, cyan, magenta and yellow.

8. The color conversion device according to claim 1, wherein each of said second comparison-result data is determined from two of the first comparison-result data and is effective for only one of the six inter-hue areas of red-yellow, yellow-green, green-cyan, cyan-blue, blue-magenta, and magenta-red.

9. The color conversion device according to claim 1, wherein said coefficient generating means generates specified matrix coefficients Eij (i = 1 to 3, j = 1 to 3) based on a formula (5) below:

$$(Eij) = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \qquad \ldots(5)$$

and generates the matrix coefficients Fij (i = 1 to 3, j = 1 to 18, or j = 1 to 19)
such that, of the coefficients Fij, the coefficients for said calculation result data are set to zero, and other coefficients are set to specified values.

10. The color conversion device according to claim 1, wherein

said calculating means for calculating a maximum value β and a maximum value α of said first set of three color data calculates a maximum value β and minimum value α using said first set of three color data, and generates an identification code indicating the hue data which is of a value zero, and
said second calculation means performs arithmetic operation on said hue data based on the identification code outputted from said first calculation means,
said coefficient generating means generates said matrix coefficients based on the identification code outputted from said first calculation means, and

said matrix calculator performs matrix calculation using the coefficient from said coefficient generating means to produce second set of three color data based on the identification code outputted from said first calculation means.

11. A method of converting image data from a first set of colour component data to a second set of colour component data using calculations wherein the calculations include coefficients for adjusting hues and coefficients for adjusting inter-hue regions.

12. Apparatus for converting image data from a first set of colour component data to second set of colour component data comprising means for calculating the second colour component data using the first set of colour component data and coefficients for adjusting hues and coefficients for adjusting inter-hue regions.

13. A computer program for performing a method as claimed in claim 11.

14. A computer-readable medium storing a program as claimed in claim 13.

FIG.1

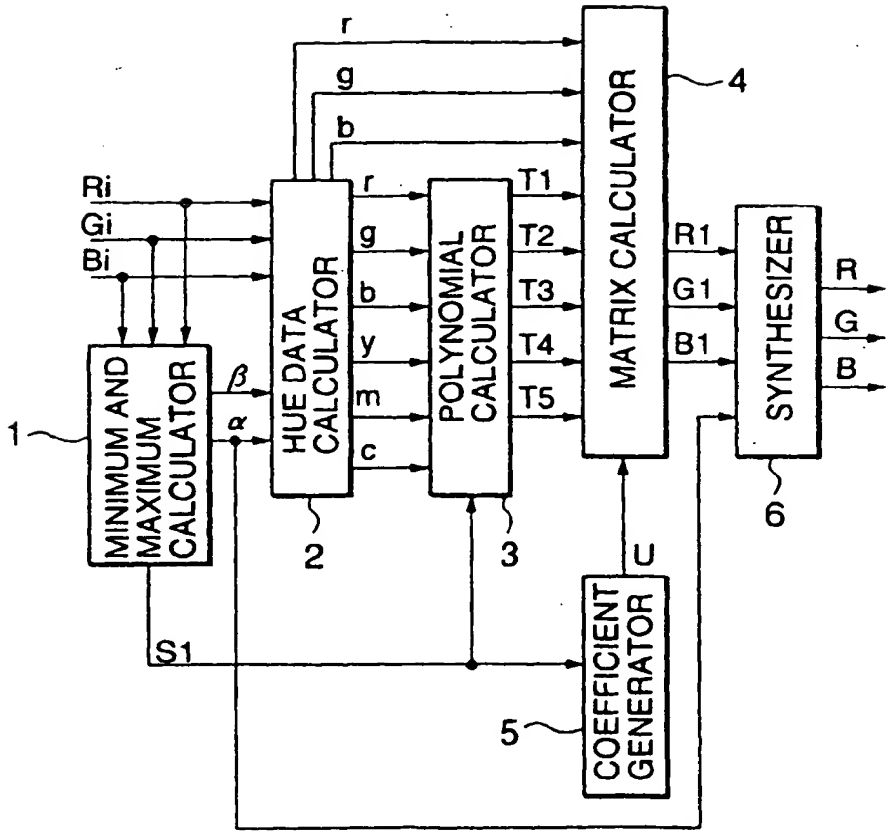

r
g
b
4
Ri
Gi
Bi
r
g
b
y
m
c
T1
T2
T3
T4
T5
R1
G1
B1
R
G
B
MINIMUM AND MAXIMUM CALCULATOR
HUE DATA CALCULATOR
POLYNOMIAL CALCULATOR
MATRIX CALCULATOR
SYNTHESIZER
1
2
3
6
β
α
S1
U
COEFFICIENT GENERATOR
5

FIG.2

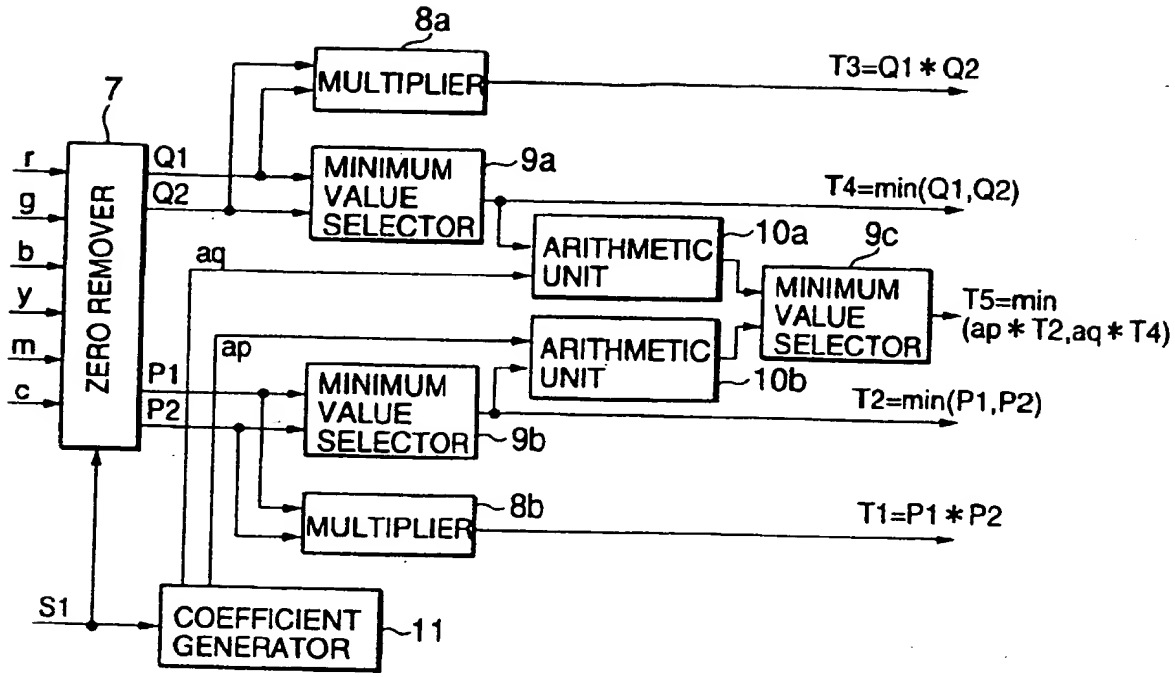


FIG.3

IDENTIFICATION CODE S1	MAXIMUM VALUE β	MINIMUM VALUE α	HUE DATA OF A VALUE ZERO
0	Ri	Gi	g,c
1	Ri	Bi	b,c
2	Gi	Ri	r,m
3	Gi	Bi	b,m
4	Bi	Ri	r,y
5	Bi	Gi	g,y

* $r=Ri-\alpha$, $g=Gi-\alpha$, $b=Bi-\alpha$
$y=\beta-Bi$, $m=\beta-Gi$, $c=\beta-Ri$

FIG.4

IDENTIFICATION CODE S1	Q1	Q2	P1	P2
0	r	b	m	y
1	r	g	y	m
2	g	b	c	y
3	g	r	y	c
4	b	g	c	m
5	b	r	m	c

FIG.5

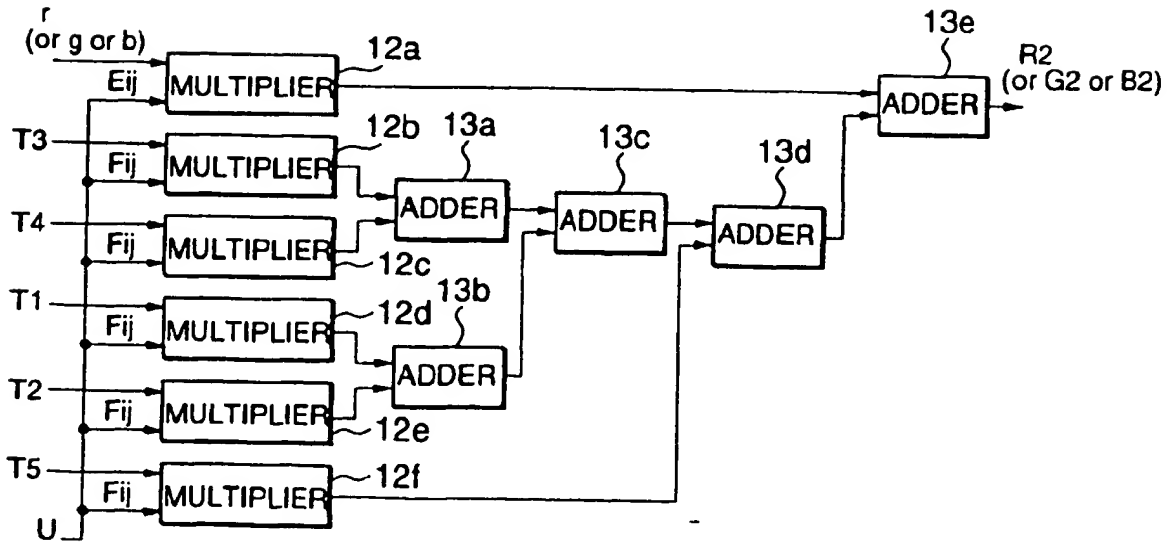


FIG.6A

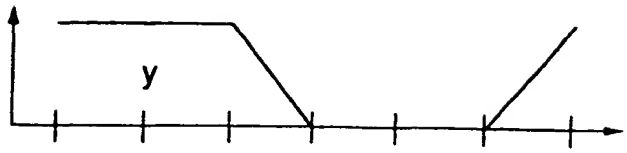


FIG.6B

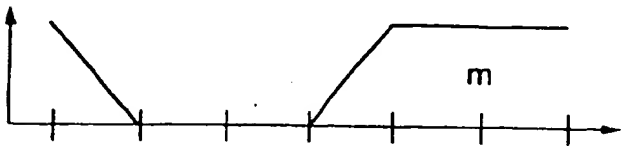


FIG.6C

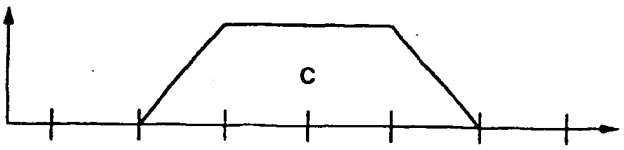


FIG.6D

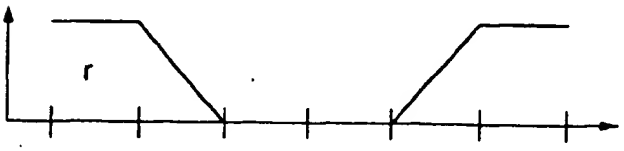


FIG.6E

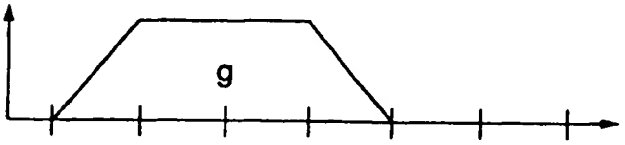


FIG.6F

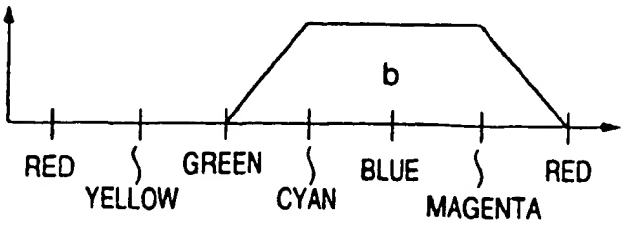


FIG.7A

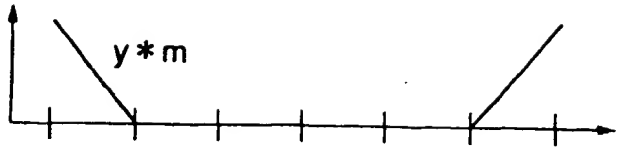


FIG.7B

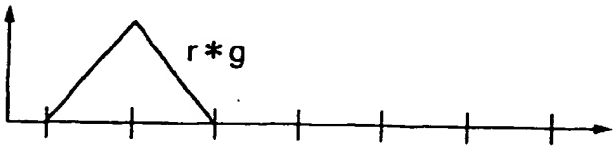


FIG.7C

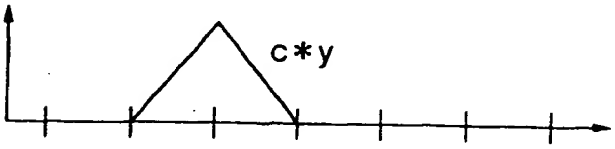


FIG.7D

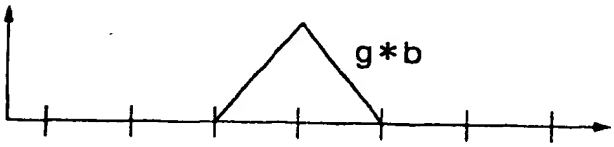


FIG.7E

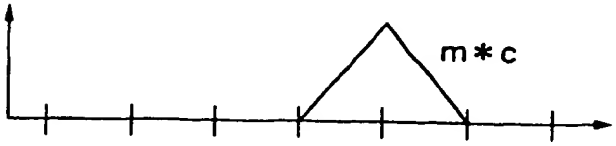


FIG.7F

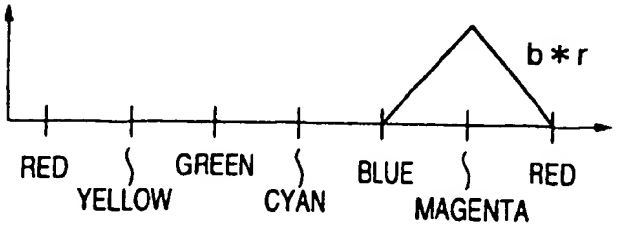


FIG.8A

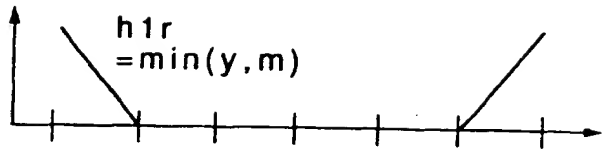


FIG.8B

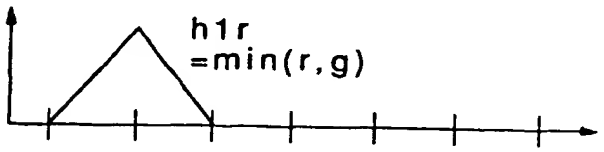


FIG.8C

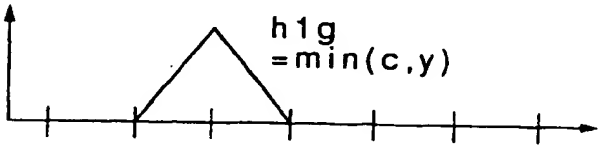


FIG.8D

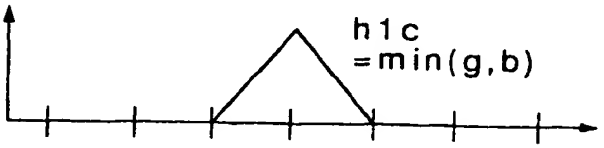


FIG.8E

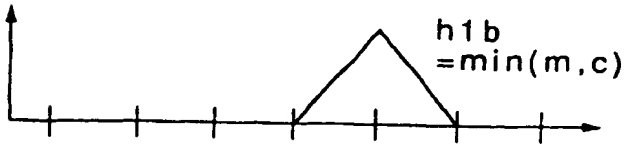


FIG.8F

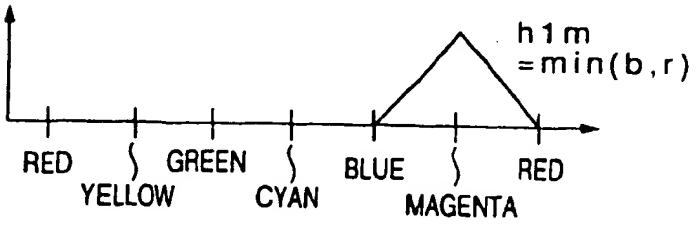


FIG.9A

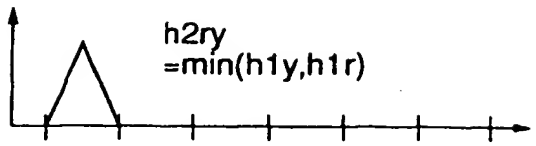


FIG.9B

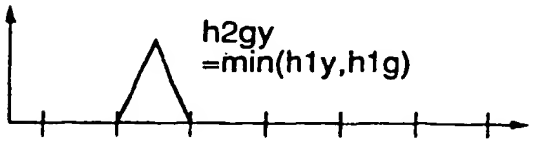


FIG.9C

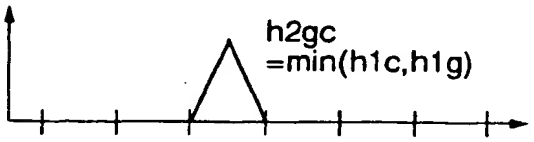


FIG.9D

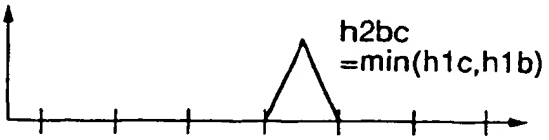


FIG.9E

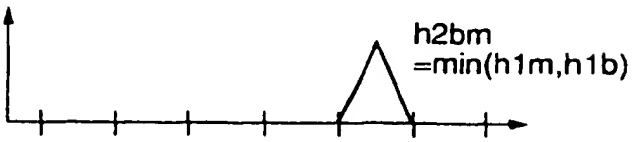


FIG.9F

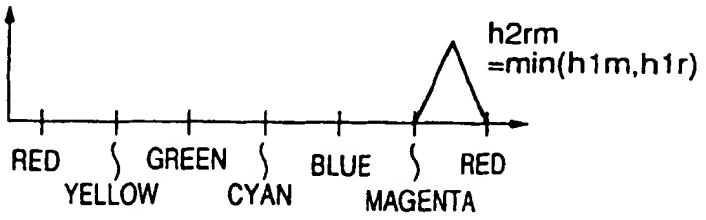


FIG.10A

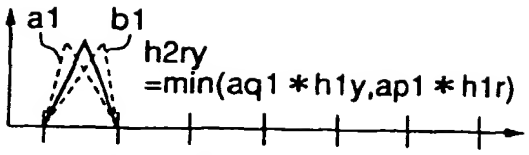


FIG.10B

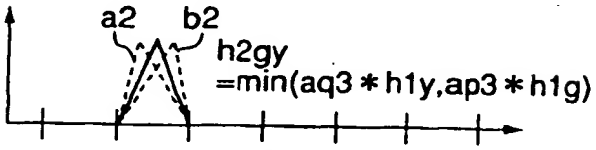


FIG.10C

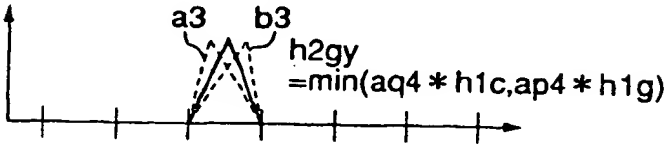


FIG.10D

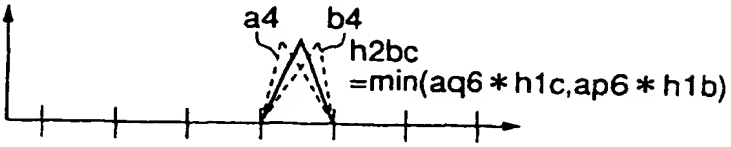


FIG.10E

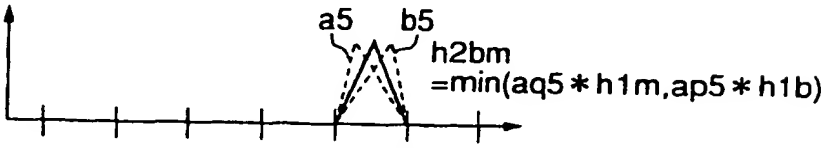


FIG.10F

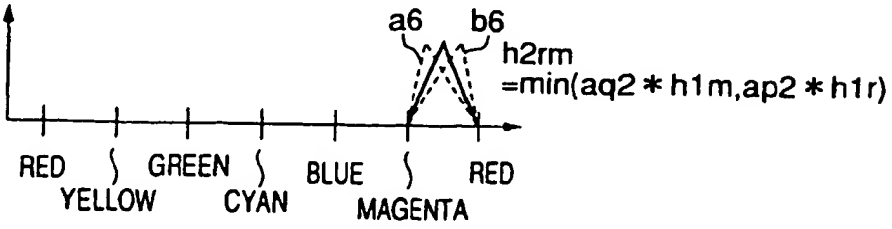


FIG.11A

HUE	EFFECTIVE SECOND-ORDER TERM	EFFECTIVE FIRST COMPARISON-RESULT DATA
RED	mxy	h1r
GREEN	yxc	h1g
BLUE	cxm	h1b
CYAN	gxb	h1c
MAGENTA	bxr	h1m
YELLOW	rxg	h1y

FIG.11B

INTER-HUE AREA	EFFECTIVE SECOND COMPARISON-RESULT DATA
RED-YELLOW	h2ry
YELLOW-GREEN	h2gy
GREEN-CYAN	h2gc
CYAN-BLUE	h2bc
BLUE-MAGENTA	h2bm
MAGENTA-RED	h2rm

FIG.12

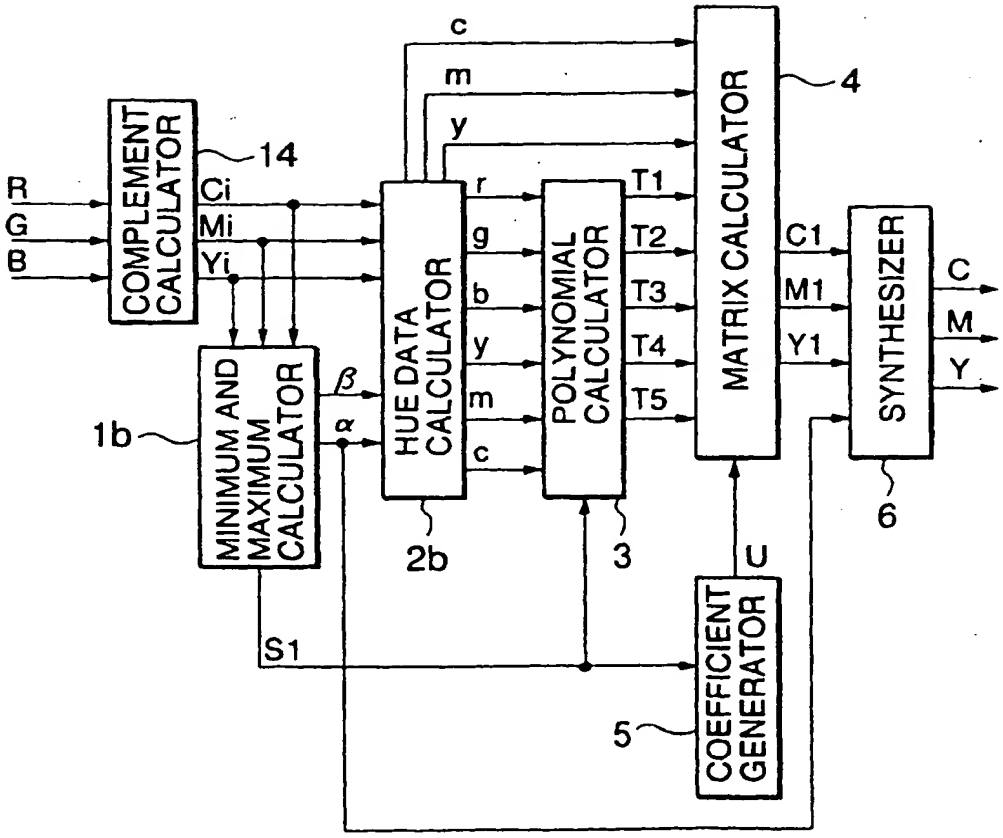

R
G
B
COMPLEMENT CALCULATOR
14
Ci
Mi
Yi
MINIMUM AND MAXIMUM CALCULATOR
1b
β
α
HUE DATA CALCULATOR
2b
r
g
b
y
m
c
POLYNOMIAL CALCULATOR
3
T1
T2
T3
T4
T5
c
m
y
MATRIX CALCULATOR
4
C1
M1
Y1
SYNTHESIZER
6
C
M
Y
S1
COEFFICIENT GENERATOR
5
C

FIG.13

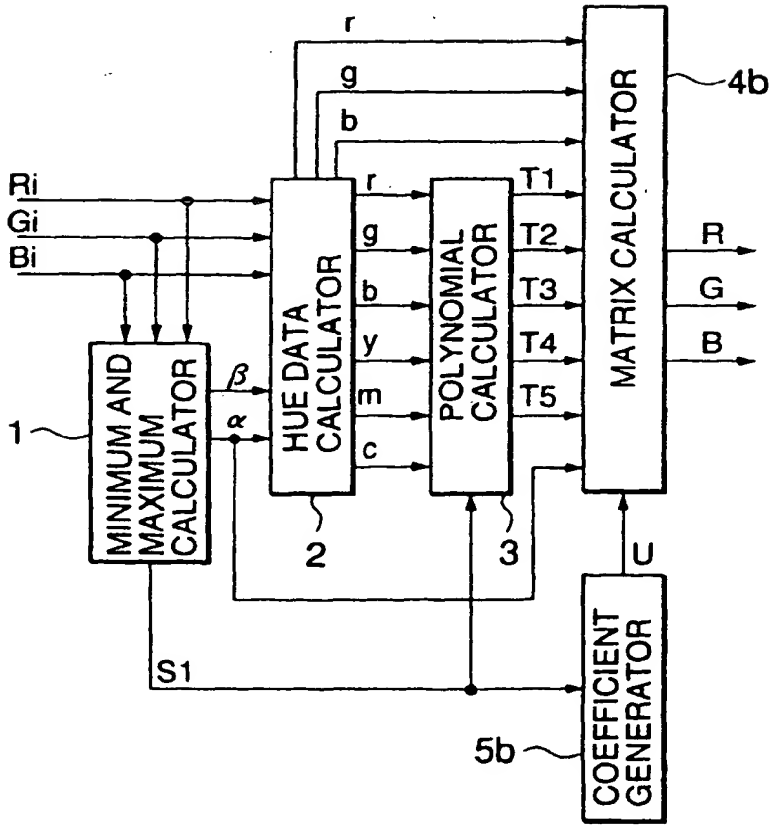

r
g
b
4b
Ri
Gi
Bi
r
g
b
y
m
c
T1
T2
T3
T4
T5
R
G
B
MATRIX CALCULATOR
POLYNOMIAL CALCULATOR
HUE DATA CALCULATOR
MINIMUM AND MAXIMUM CALCULATOR
β
α
1
2
3
U
S1
5b
COEFFICIENT GENERATOR

FIG.14

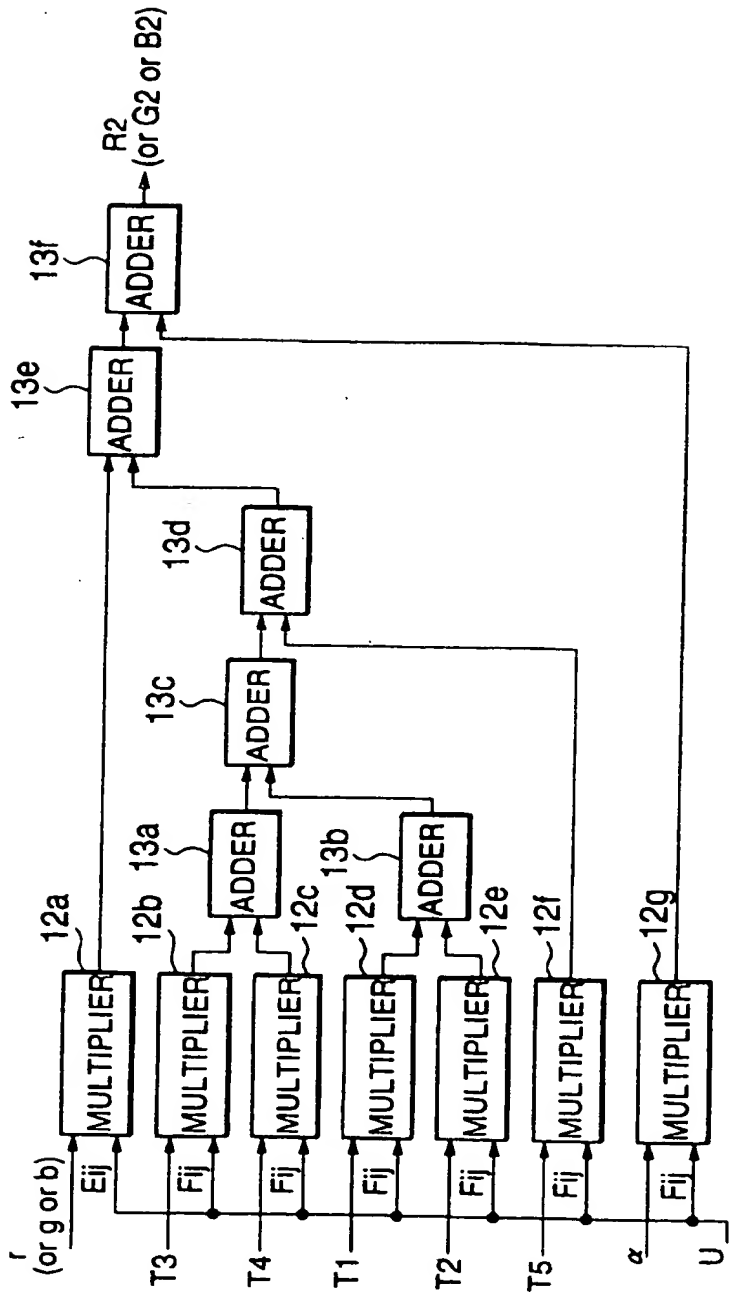

r (or g or b)
Eij
MULTIPLIER
12a
12b
12c
12d
12e
12f
12g
Fij
T3
T4
T1
T2
T5
α
U
ADDER
13a
13b
13c
13d
13e
13f
R2 (or G2 or B2)

FIG.15

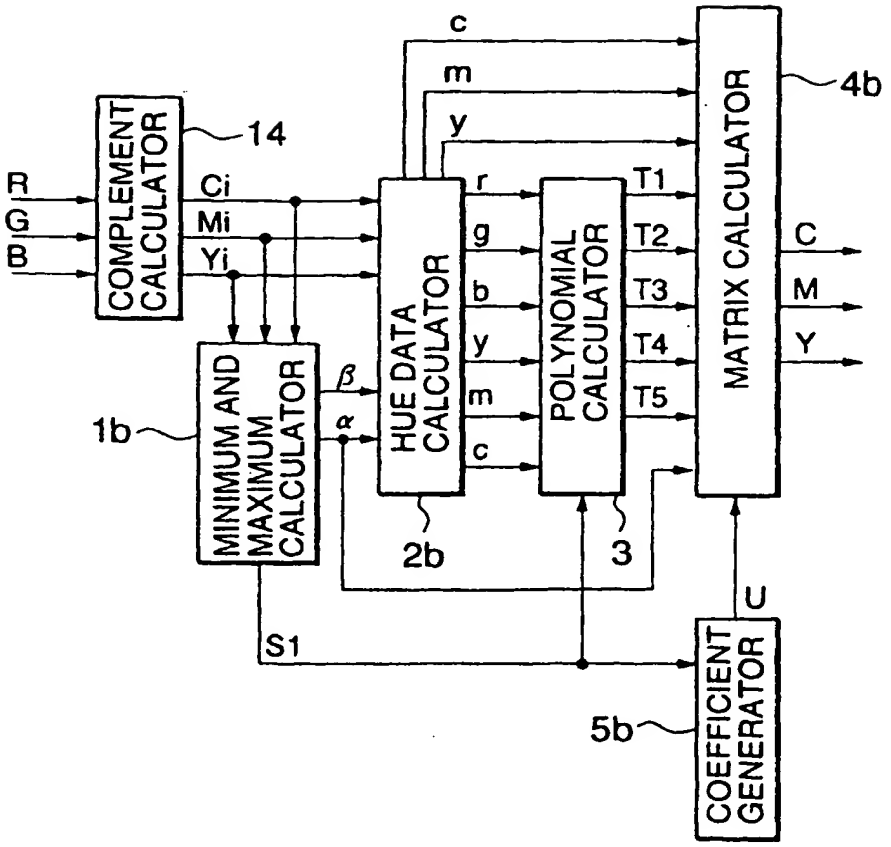

R
G
B
COMPLEMENT CALCULATOR
14
Ci
Mi
Yi
MINIMUM AND MAXIMUM CALCULATOR
1b
β
α
HUE DATA CALCULATOR
2b
c
m
y
r
g
b
y
m
c
POLYNOMIAL CALCULATOR
3
T1
T2
T3
T4
T5
MATRIX CALCULATOR
4b
C
M
Y
S1
COEFFICIENT GENERATOR
5b
C

FIG. 16

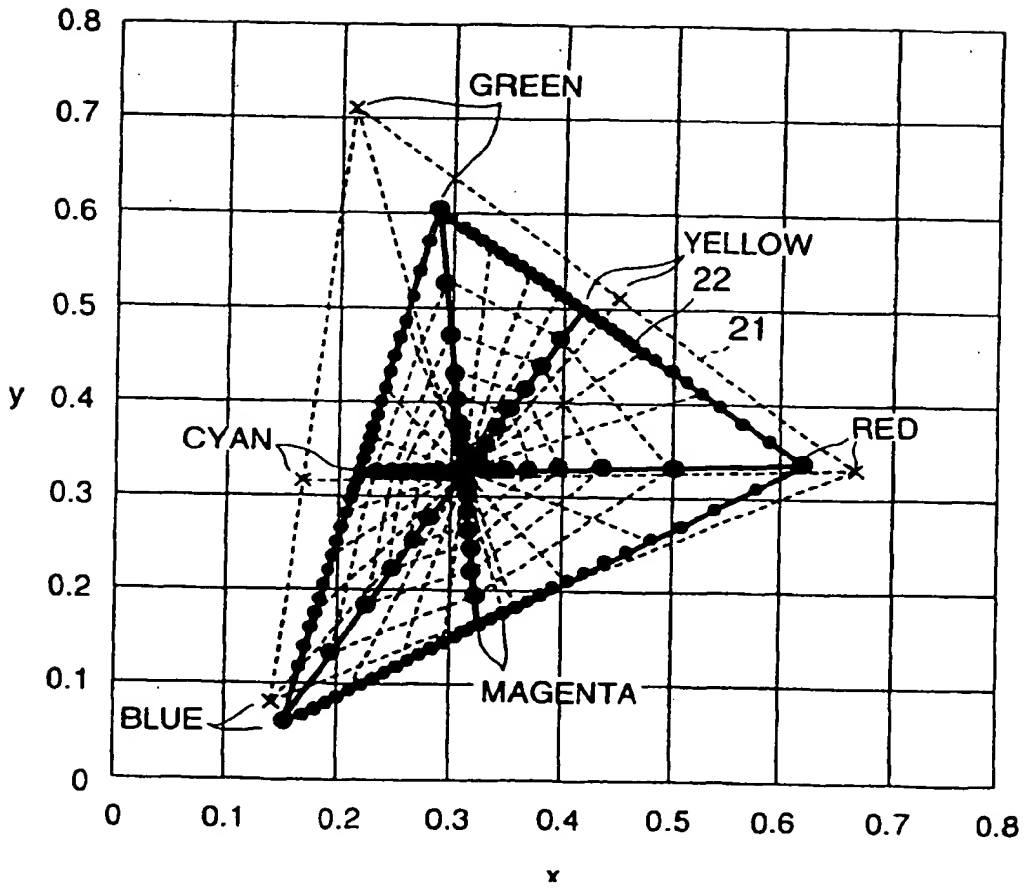

0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
y
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
x
GREEN
YELLOW
22
21
CYAN
RED
MAGENTA
BLUE

FIG. 17

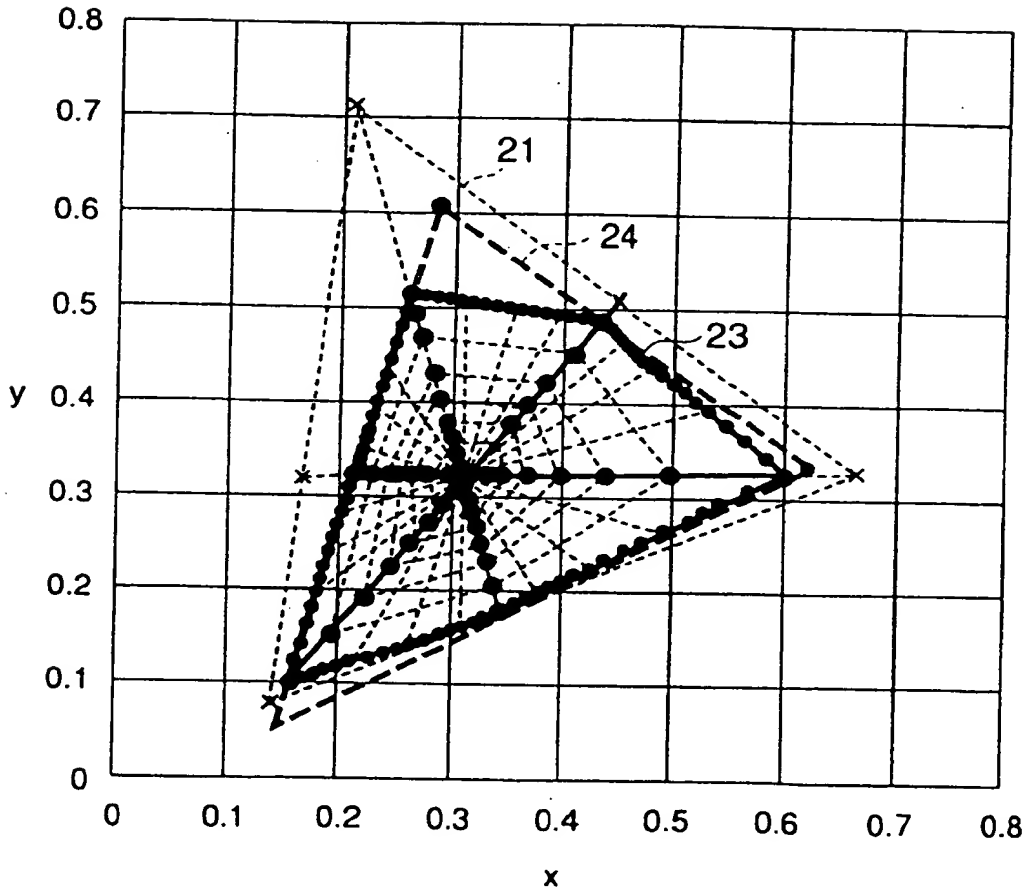


FIG. 18

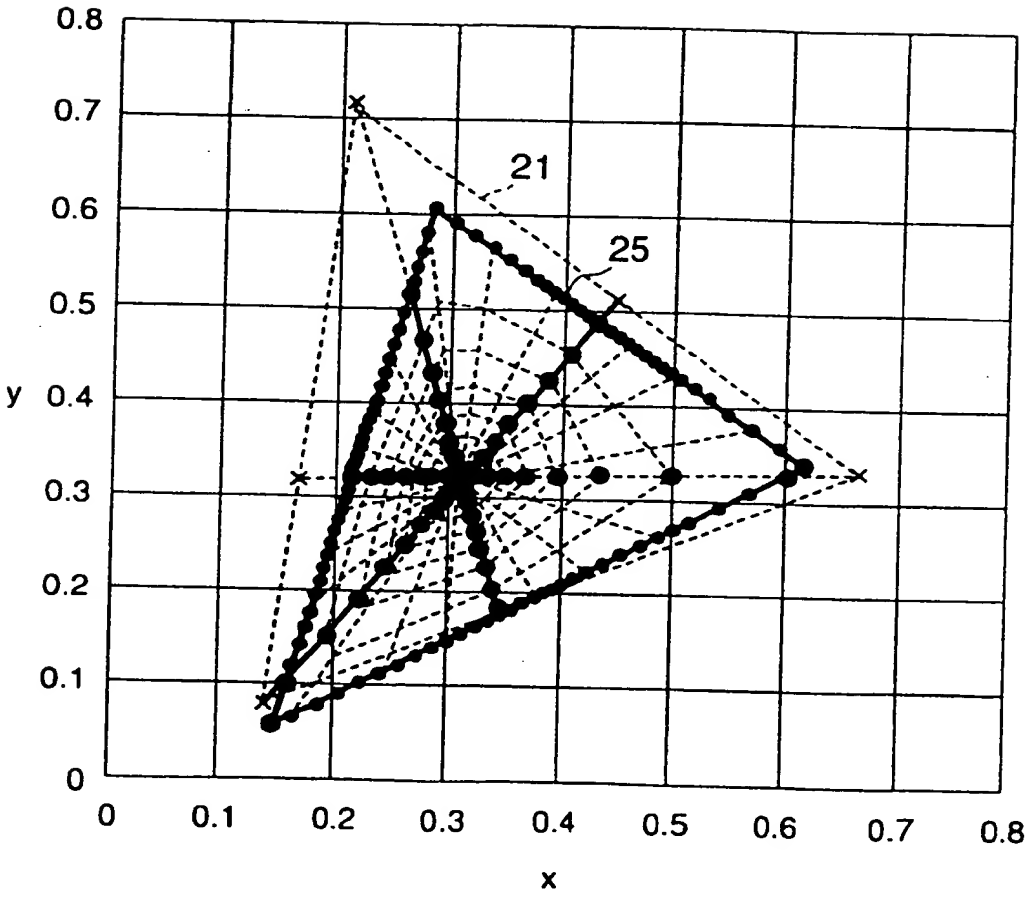


FIG.19
PRIOR ART

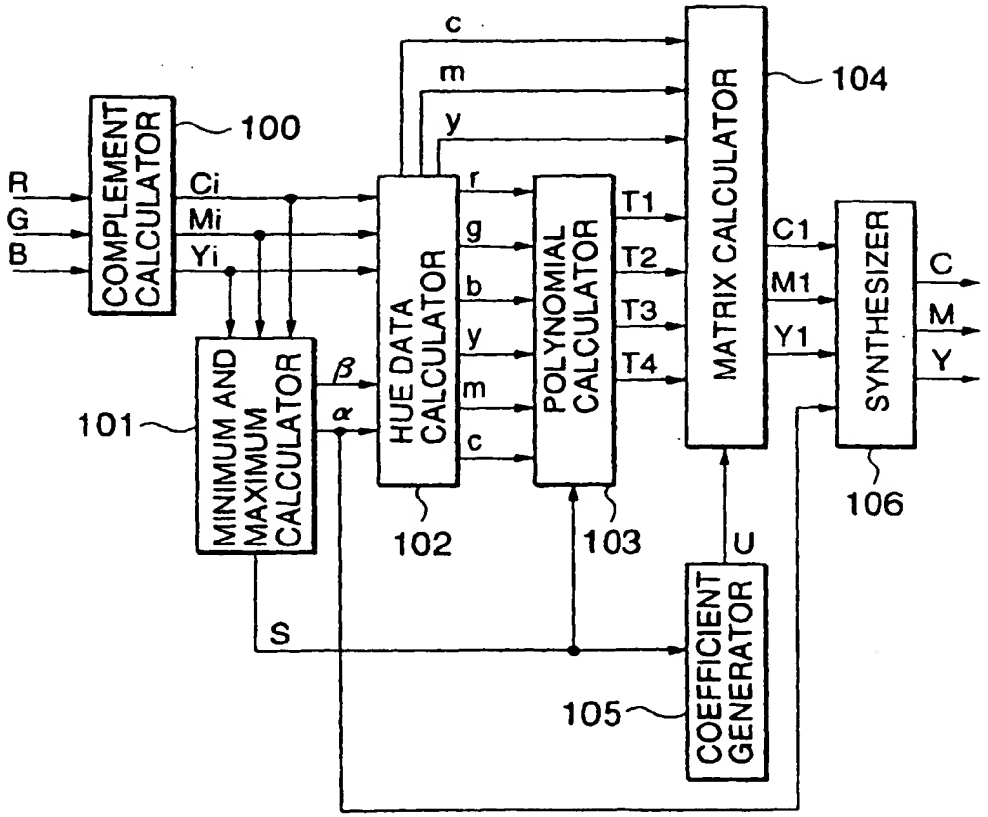


FIG.20A
PRIOR ART

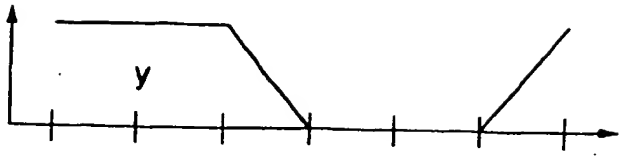


FIG.20B
PRIOR ART

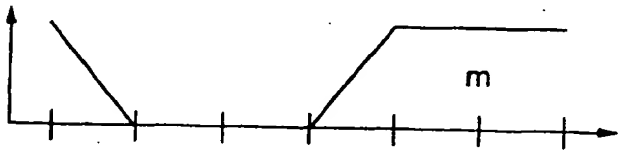


FIG.20C
PRIOR ART

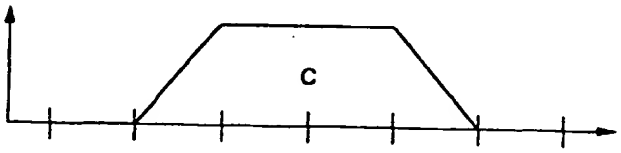


FIG.20D
PRIOR ART

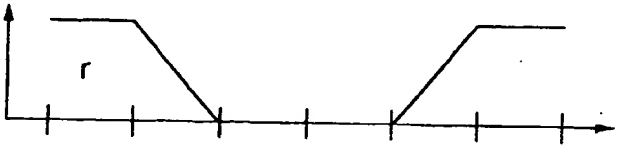


FIG.20E
PRIOR ART

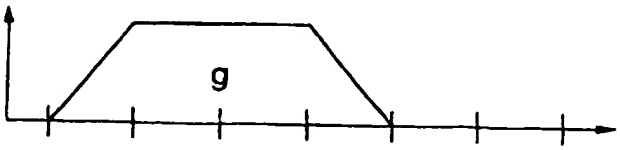


FIG.20F
PRIOR ART

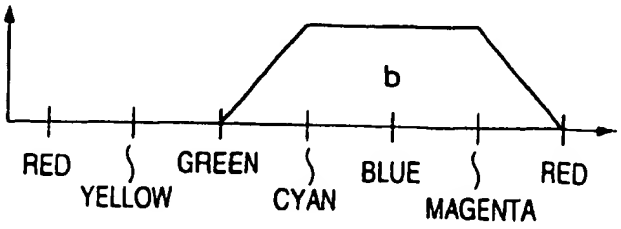


FIG.21A
PRIOR ART

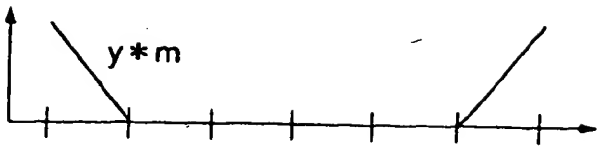


FIG.21B
PRIOR ART

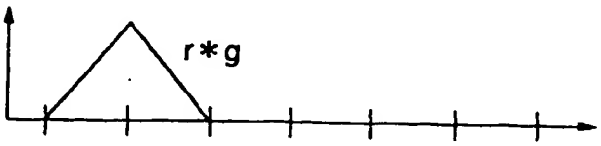


FIG.21C
PRIOR ART

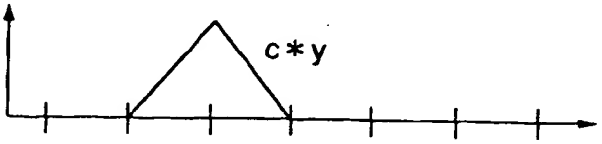


FIG.21D
PRIOR ART

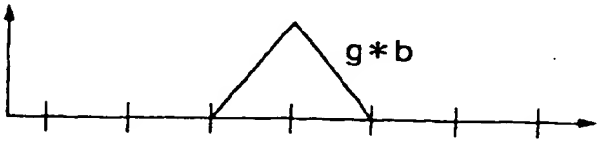


FIG.21E
PRIOR ART

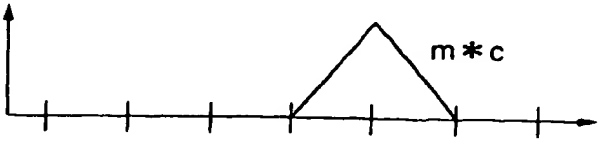
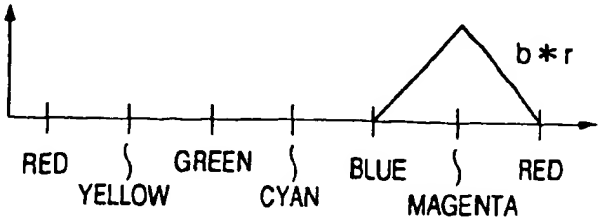


FIG.21F
PRIOR ART



(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 028 586 A3

(12) EUROPEAN PATENT APPLICATION

(88) Date of publication A3:
29.05.2002 Bulletin 2002/22

(51) Int Cl.[7]: **H04N 1/60**

(43) Date of publication A2:
16.08.2000 Bulletin 2000/33

(21) Application number: **99309859.9**

(22) Date of filing: **08.12.1999**

(84) Designated Contracting States:
AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE
Designated Extension States:
AL LT LV MK RO SI

(30) Priority: **27.01.1999 JP 1821799**
16.11.1999 JP 32600599

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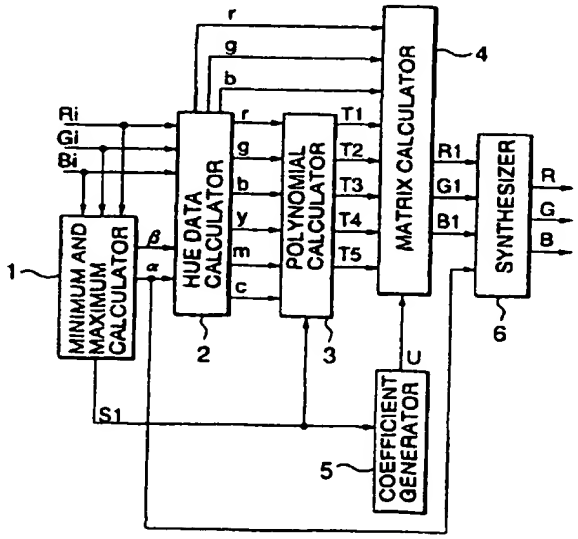
(54) Color conversion device and color conversion method

(57) By changing coefficients of first comparison-result data relating to respective hues, and and second comparison-result data relating to respective inter-hue areas, only the target hue or inter-hue area among the six hues of red, blue, green, yellow, cyan, and magenta, and the six inter-hue areas can be varied, without affecting other hues and inter-hue areas. Thus, the six hues and six inter-hue areas can be varied independently, and the large-capacity memory is not required.

FIG.1



EP 1 028 586 A3

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EUROPEAN SEARCH REPORT

Application Number
EP 99 30 9859

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H04N

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	10 April 2002	De Roeck, A

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